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DASIAC-TN-86-15

HANDBOOK OF HE EXPLOSION EFFECTS

J. Petes
Kaman Tempo
Alexandria Office
Huntington Building
2560 Huntington Avenue
Alexandria, VA 22303-1410

11 April 1986

Technical Report

CONTRACT No. DNA 001-82-C-0274

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UNDER RDT&E RMSS CODE B337084466 P99QMXDC00001 H2590D.

Prepared for
Director
DEFENSE NUCLEAR AGENCY
Washington, DC 20305-1000

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19 ABSTRACT (Continue on reverse if necessary and identify by block number)

This Handbook is intended for use by program managers, participants in high-explosive field tests, and others requiring a ready reference to airblast and crater effects of conventional explosives. To facilitate this aim, the Handbook is in pocket- and desk-sized forms. By the use of overlays, effects parameters are available for charges 1 lb. to 10 million lbs. The overlay technique obviates the need to resort to normal scaling procedures, pencil and paper calculations, or calculators. Keywords

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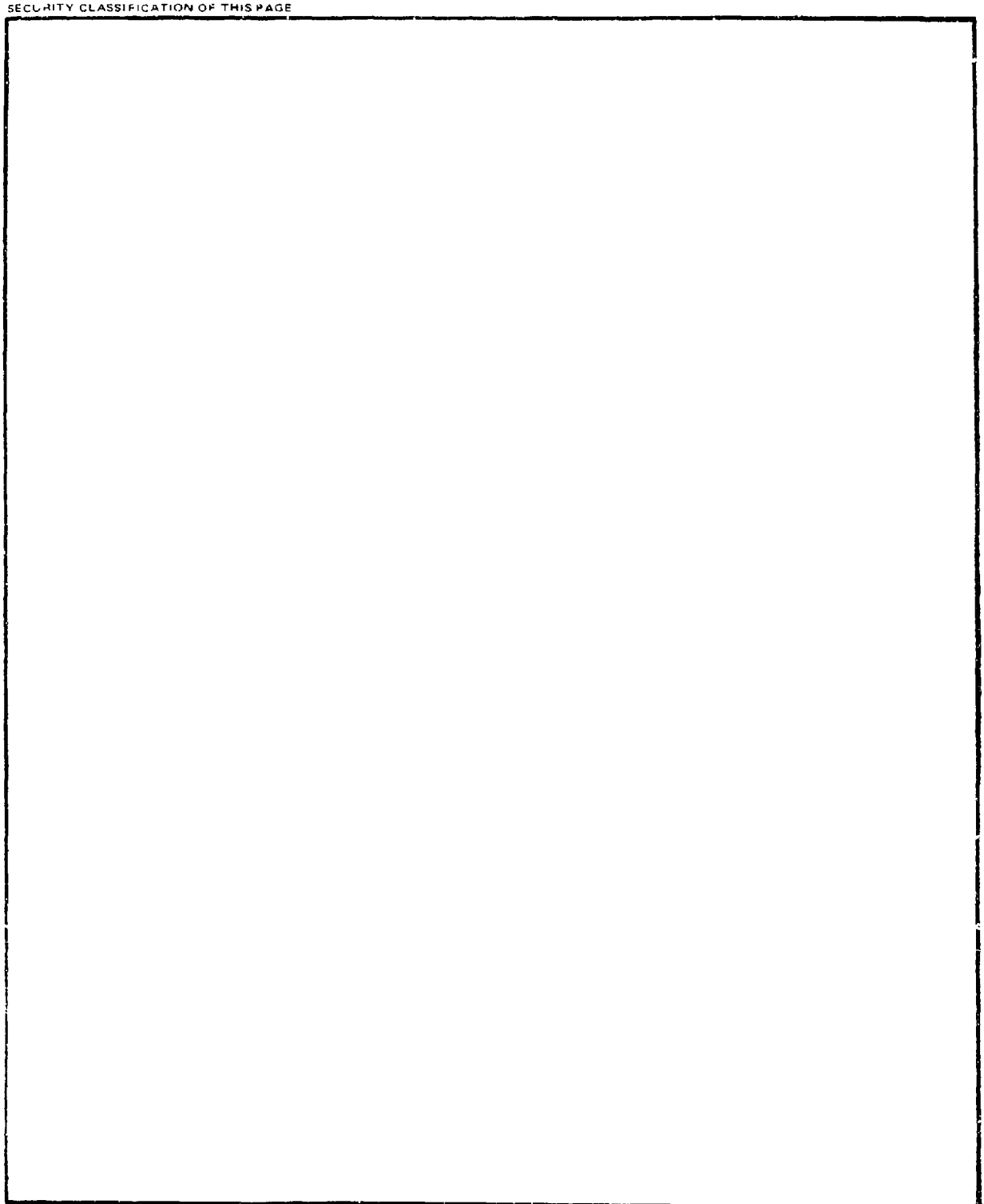


Preface

This Handbook of HE Explosion Effects is intended for use by blast experts, test planners, safety engineers, accident investigators, administrators, and other interested persons who may, at times, require a quick and reliable answer as to the effects of explosions from conventional high explosives (HE) and propellants. Overlays are used to determine major effects for charges weighing from 10^0 to 10^7 pounds without recourse to usual scaling procedures. However, most of the information is provided in a form suitable for scaling if so desired.

The data presented in this handbook are based almost completely on experimental results rather than on hydrocode calculations. The values read off of the graphs are with ±10 percent of those that would be obtained from the original source material referenced and annotated in Section 4.

The effects from only two explosives are covered in some detail: TNT, because it is common practice to relate and compare explosions from many sources to TNT explosions; and ANFO, because it has wide use in military tests where it is required to simulate nuclear weapon-proportioned blast and shock. The effects from several other explosives and propellants can be determined by use of the equivalent weight values given on page 23. (The ANFO data are not applicable to charges weighing less than about 500 pounds.)

The data given in this handbook pertain to explosions in a standard sea-level atmosphere.

Most of the information contained in this manual has been derived from the references cited in Section 4; only page 22 (on craters) introduces new information.

The overlay presentation was designed by Nancy Parnell who made the necessary calculations and original plots. The final graphic design was developed by Dennis Paulazzo and Bonnie Krueger.

J. Petes

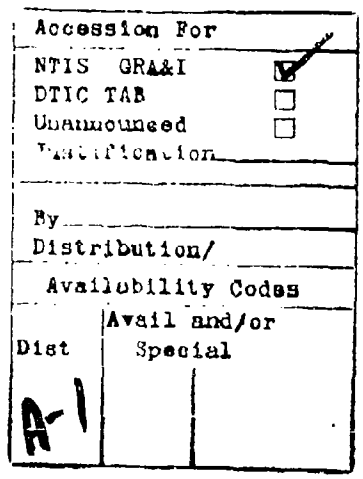


Table of Contents

Table of Contents

How To Use The Manual

Most of the effects information is presented in the form of plots for 1-pound charges, fired in a standard sea-level atmosphere. The overlays permit reading effects values for the parameters of interest for charges weighing from 10^0 to 10^7 pounds.

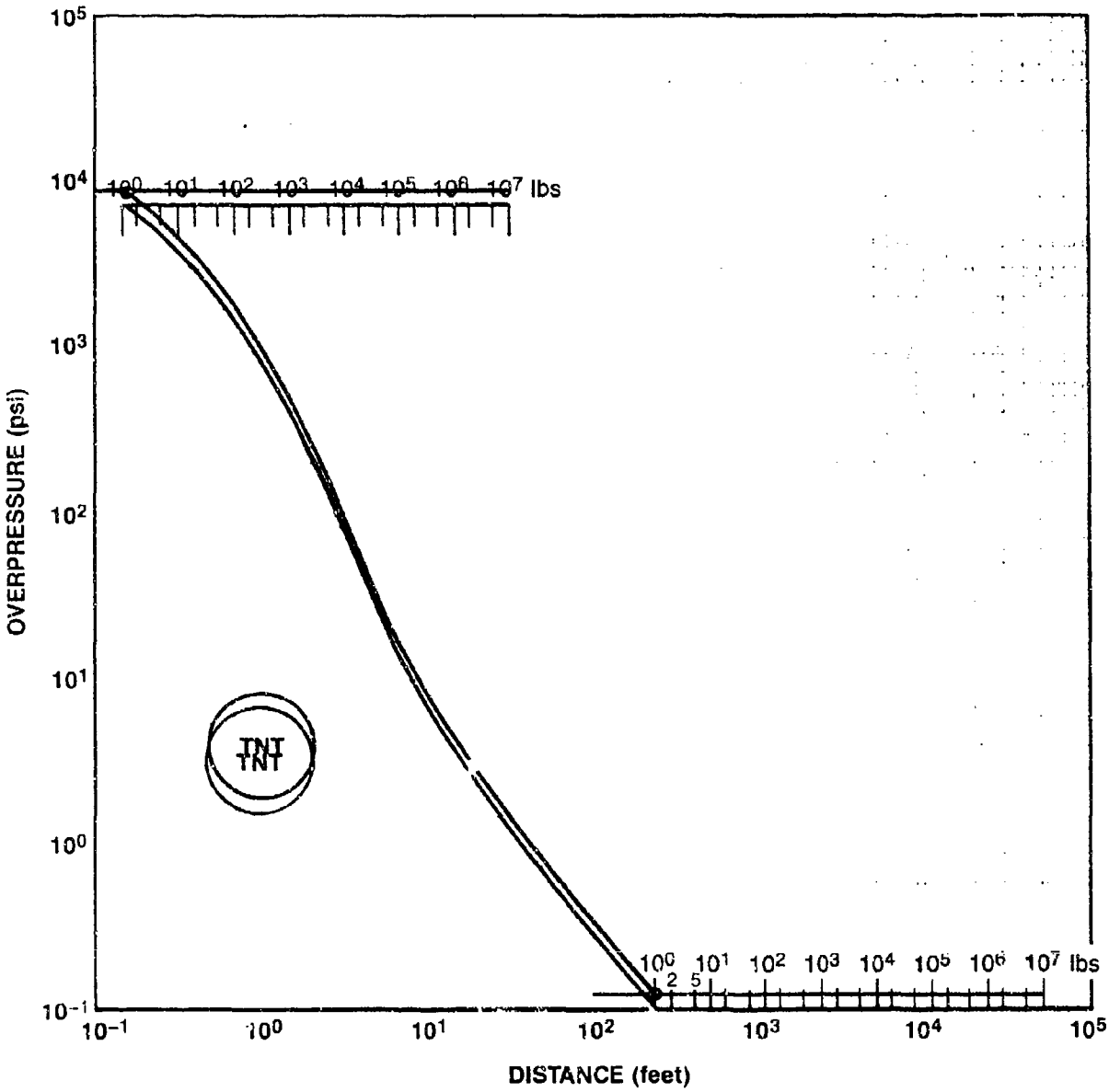
For overlays on pages 4, 5, 20, and 21, line the bottom and left axes of the overlay with the charge weight scale of interest and read the parameters directly. In a similar fashion with the remaining overlays, place the overlay on the graph, aligning the targets with the charge weight of interest on both the bottom and top weight scales and read the parameters directly.

A test example illustrating the use of the overlays is included on many of the graphs.

An alternative to using the overlays would be to use a scaling procedure to determine the required data since all plots are based on 1-pound charges. See page 24 for simplified scaling procedures.

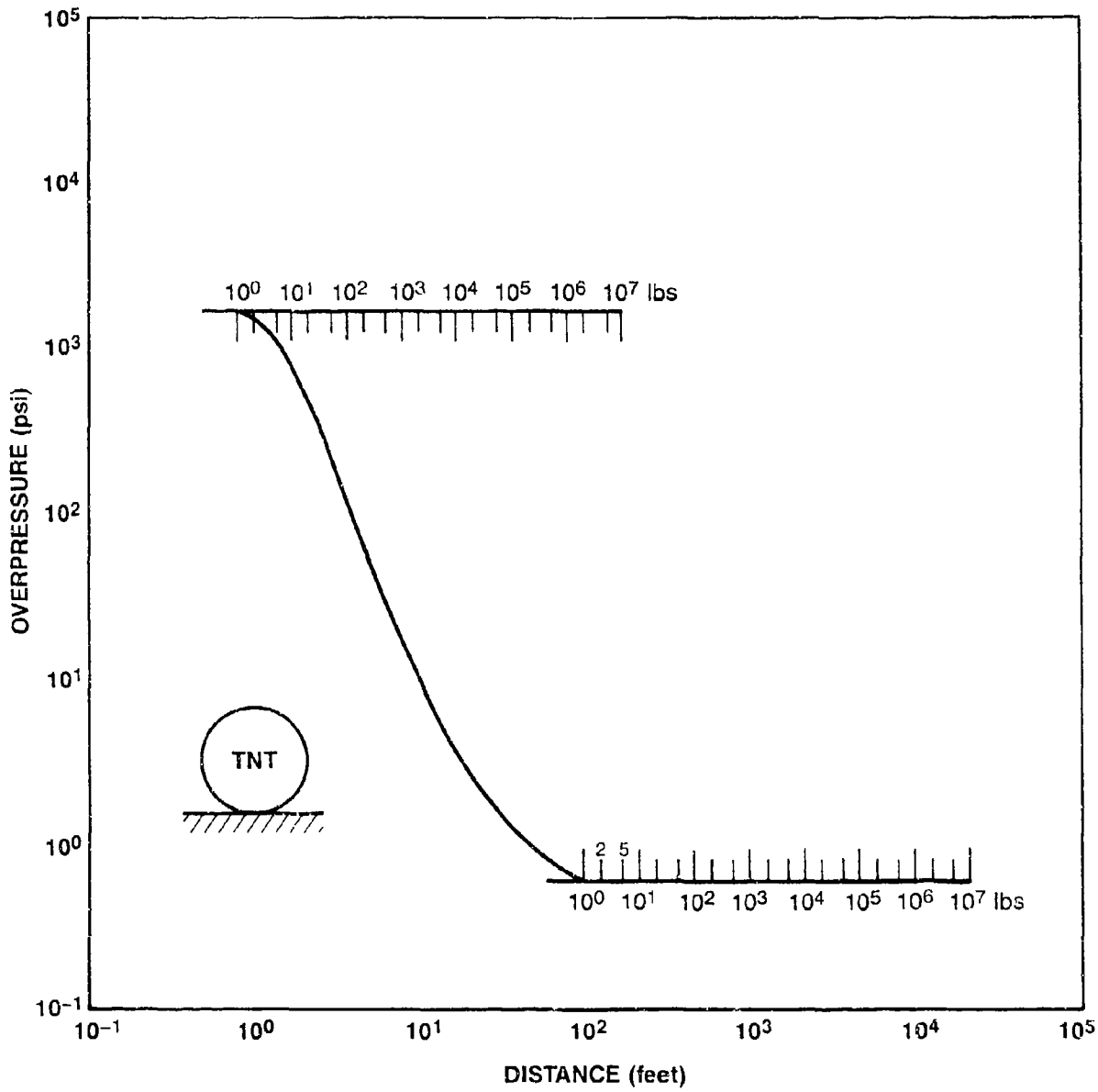
Section 1
AIRBLAST

Free Air TNT Spheres
Overpressure vs Distance



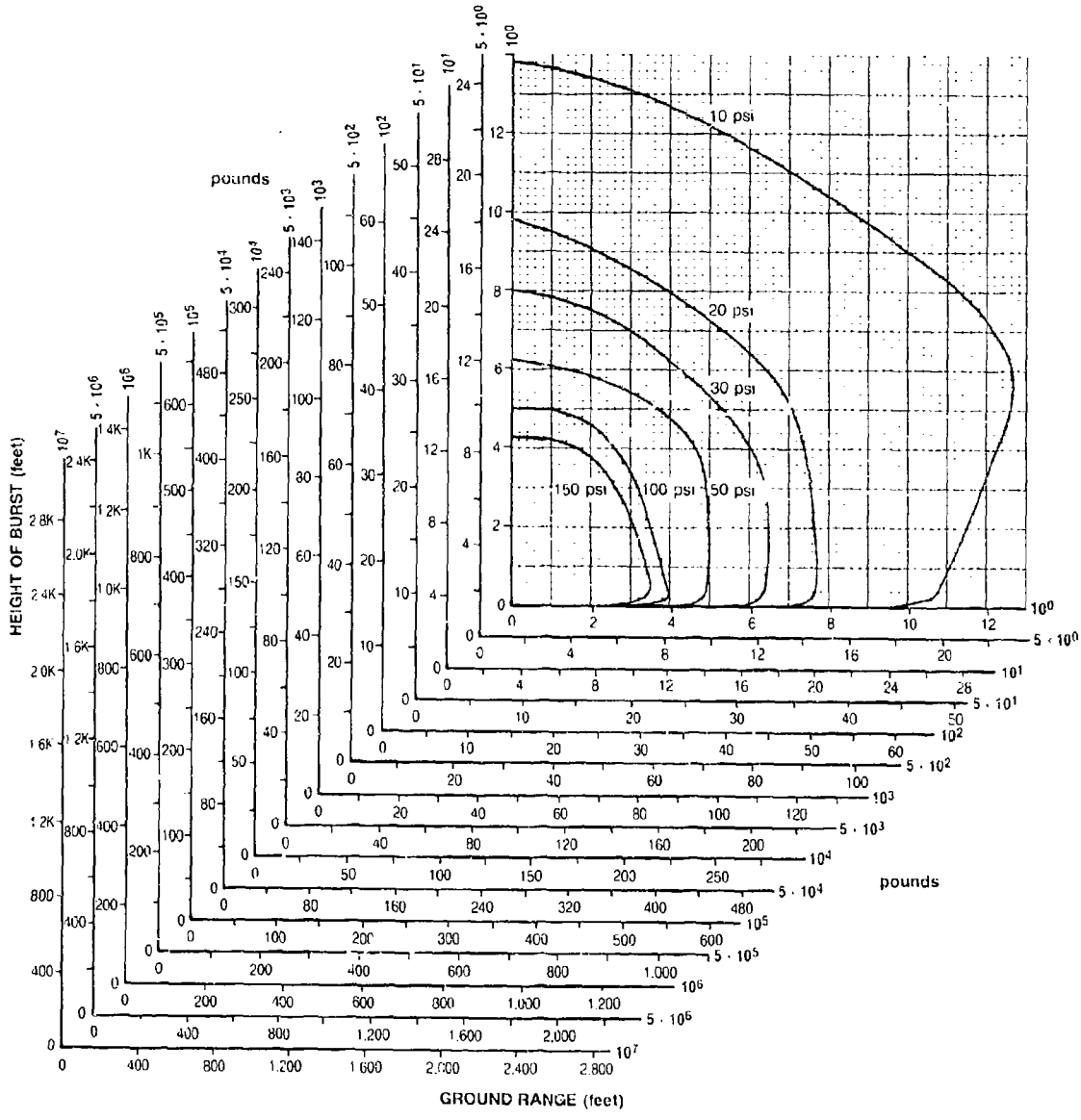
Example: For 20,000 lbs, at 1,000 feet, pressure = 1 psi

Surface TNT Spheres
Overpressure vs Distance



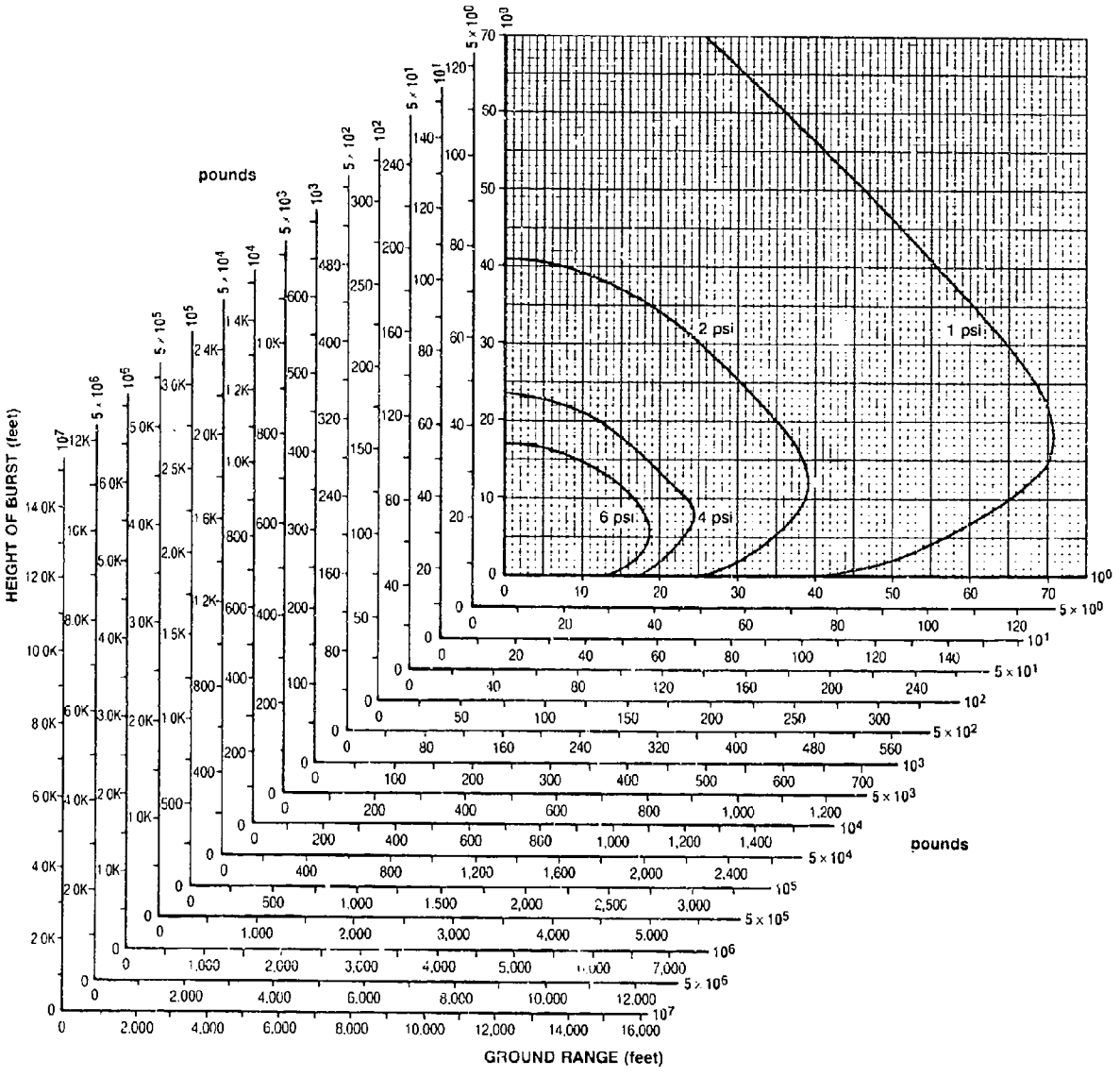
Example: For 5,000 lbs, 22 psi is at 125 feet

TNT Spheres/Intermediate-Pressure
Height of Burst vs Ground Ranges



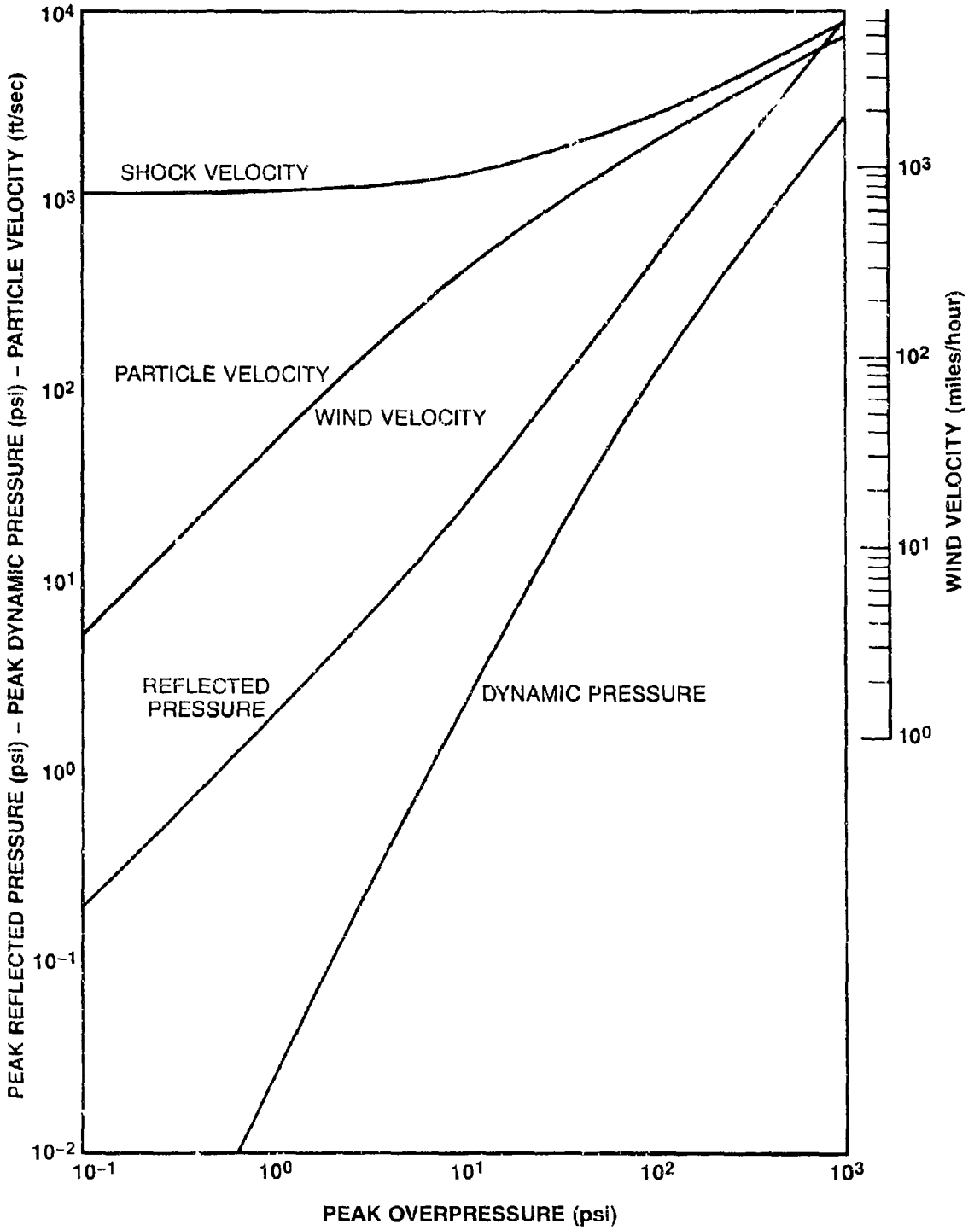
Example: For 1,000 lbs at an HOB = 50 feet, 20 psi is at 68 feet

TNT Spheres/Low-Pressure
Height of Burst vs Ground Ranges

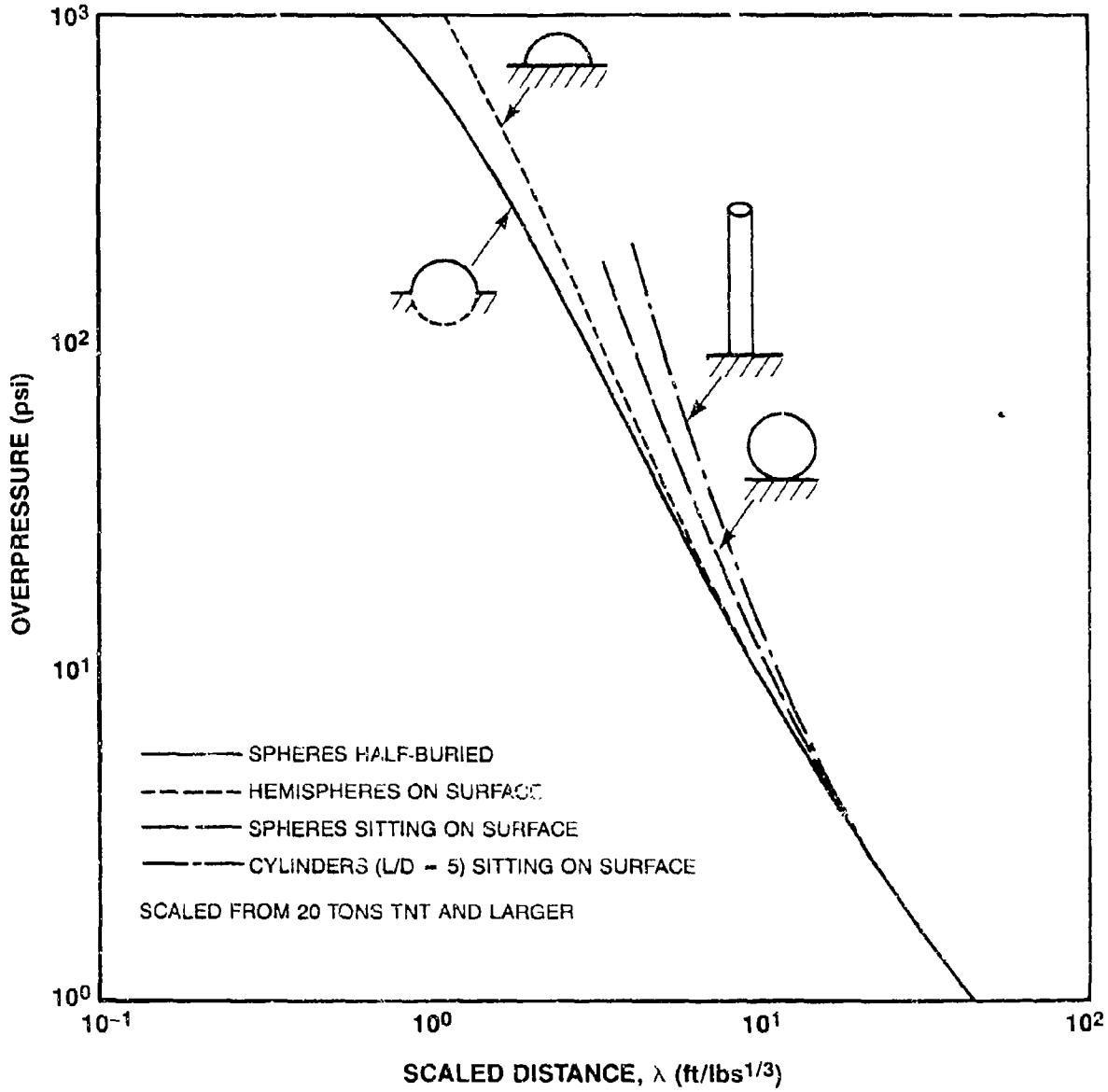


Example: For 100,000 lbs, at an HOB = 2,000 feet, 1 psi is at 2,450 feet

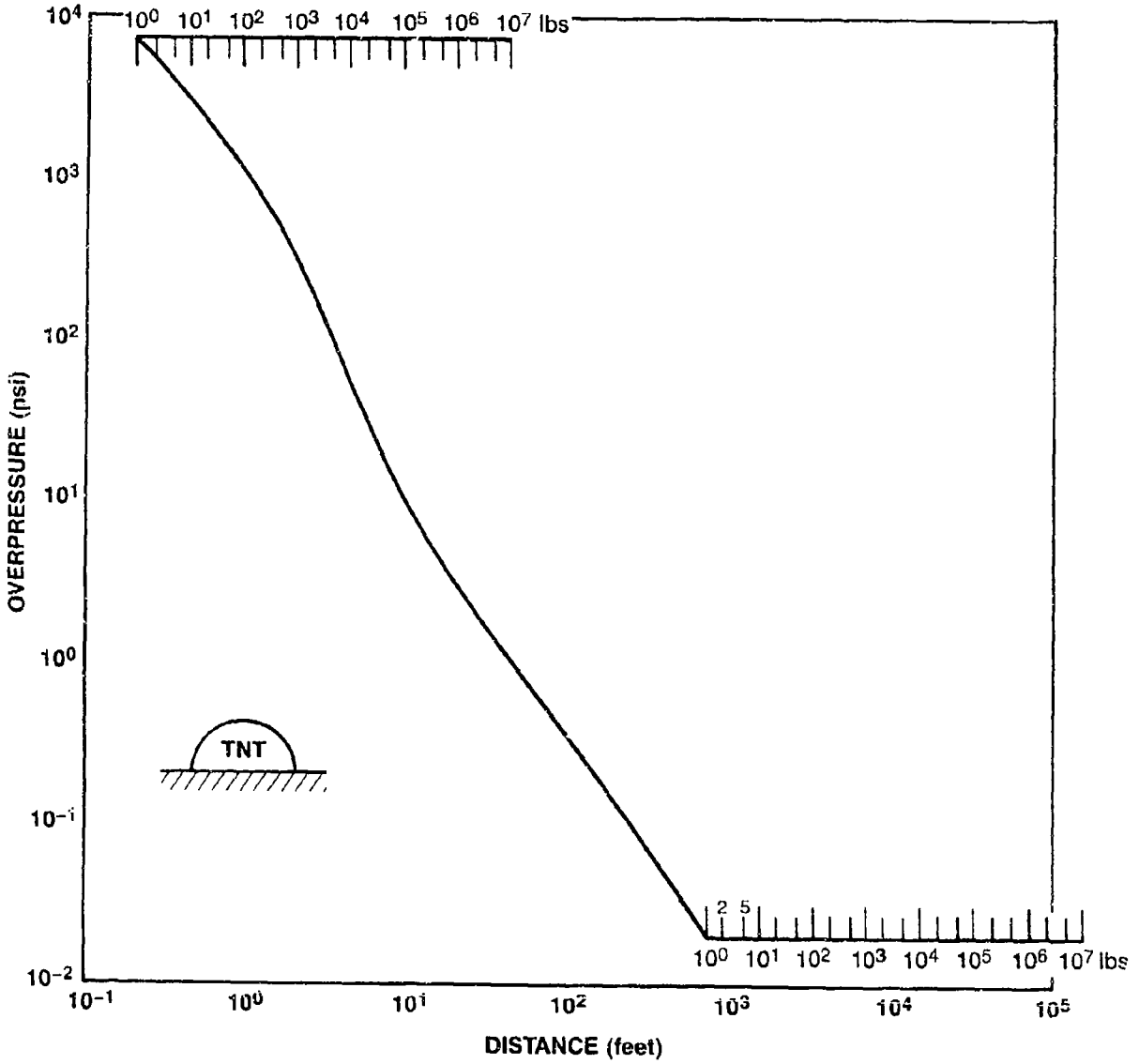
Ideal Blast Characteristics at Shock Front



Effects of Charge Geometry for Surface TNT Charges
(Overpressure vs Distance)

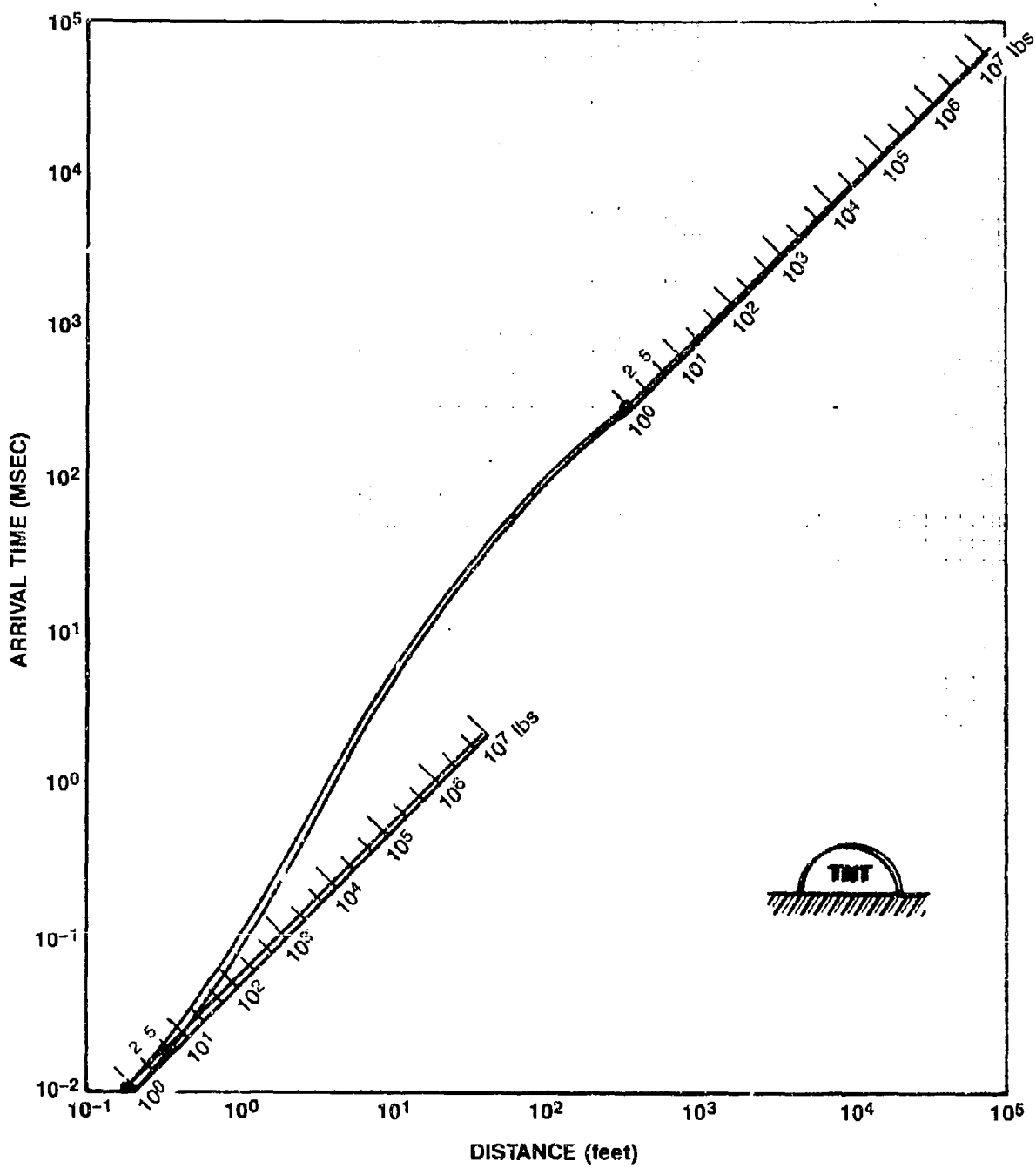


TNT Hemispheres
Overpressure vs Distance



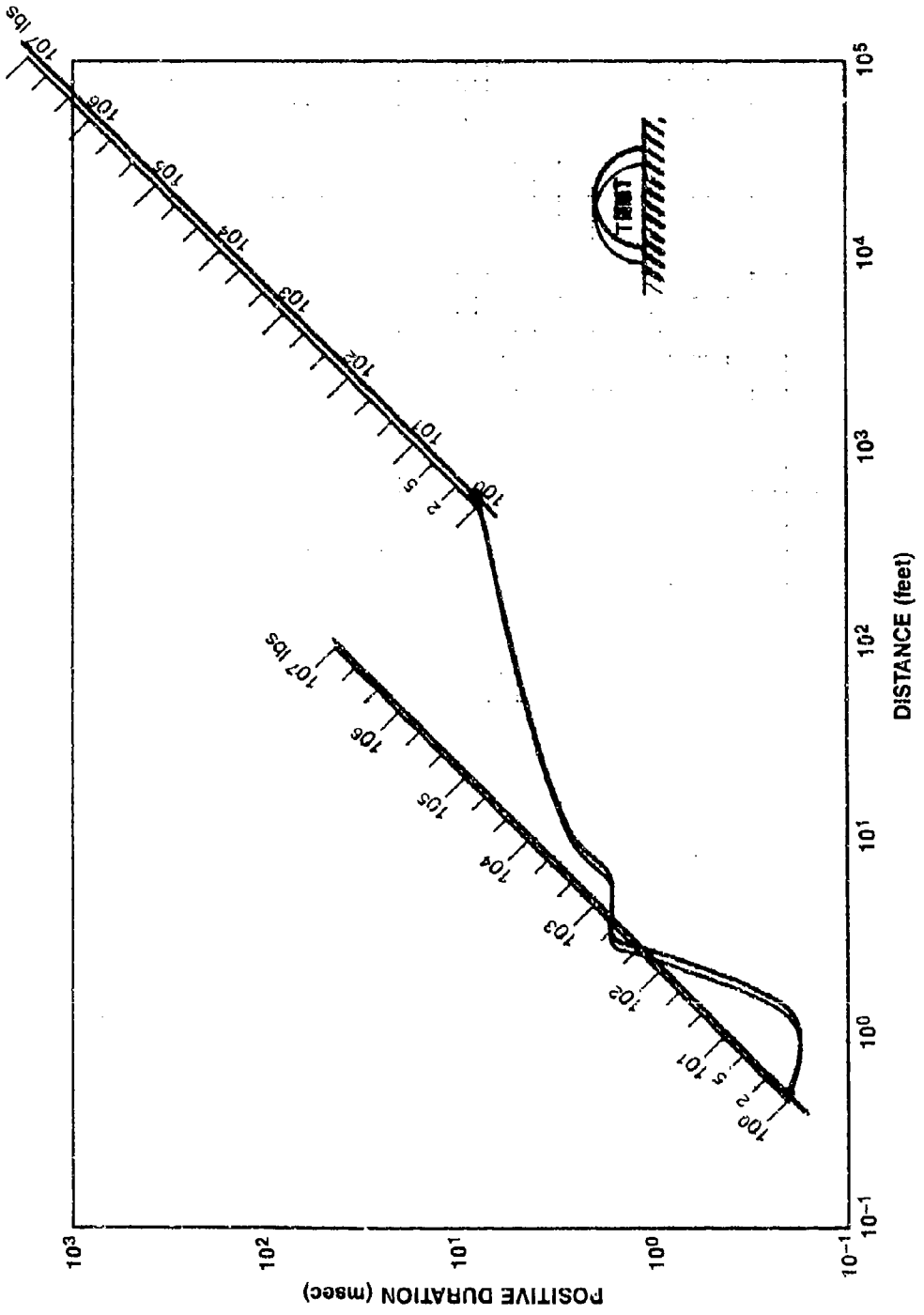
Example: For 5,000 lbs, 22 psi is at 110 feet

TNT Hemispheres
Arrival Time vs Distance



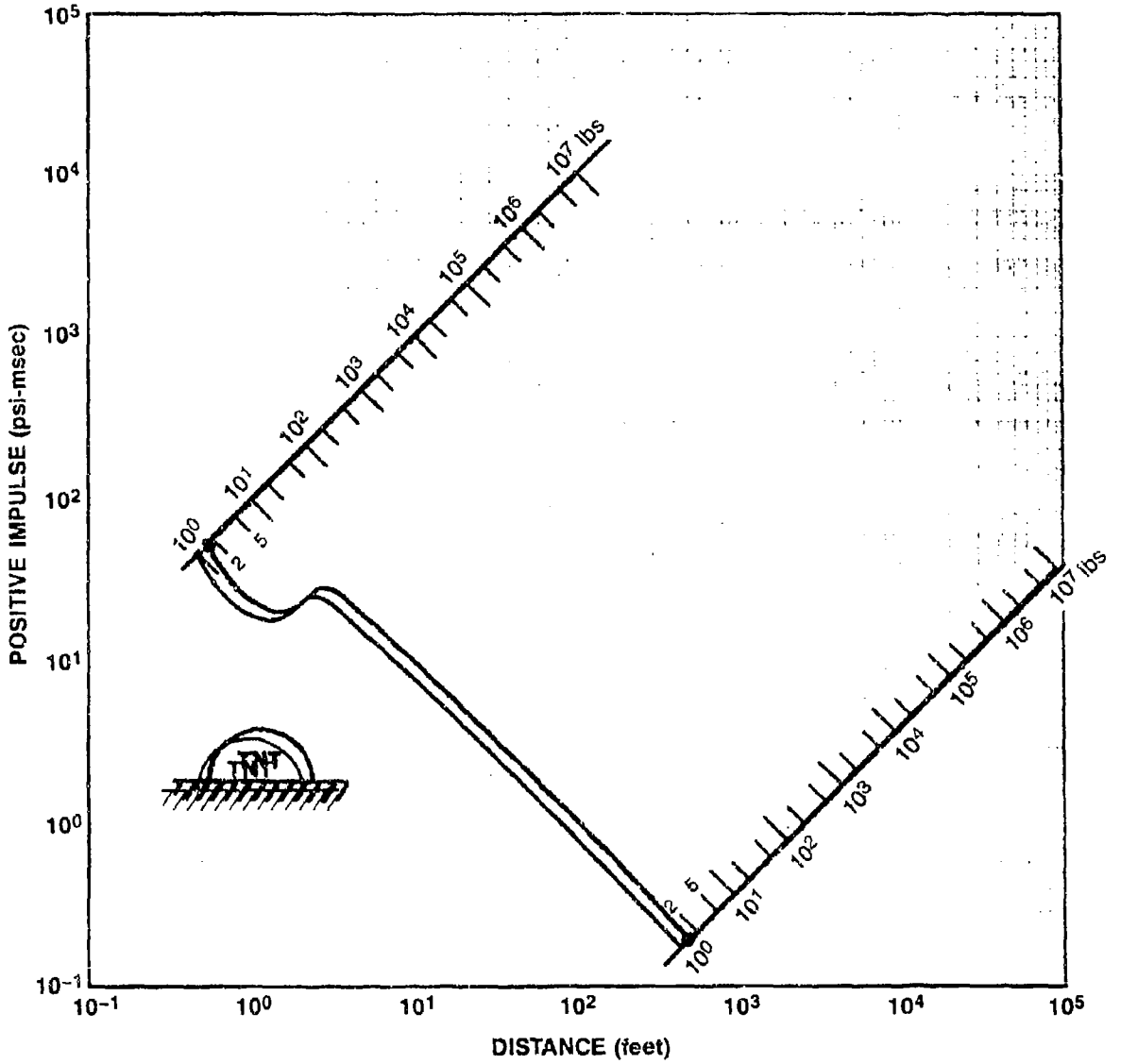
Example: For 5,000 lbs, time of arrival at 110 feet is 35 msec

TNT Hemispheres
Positive Duration vs Distance



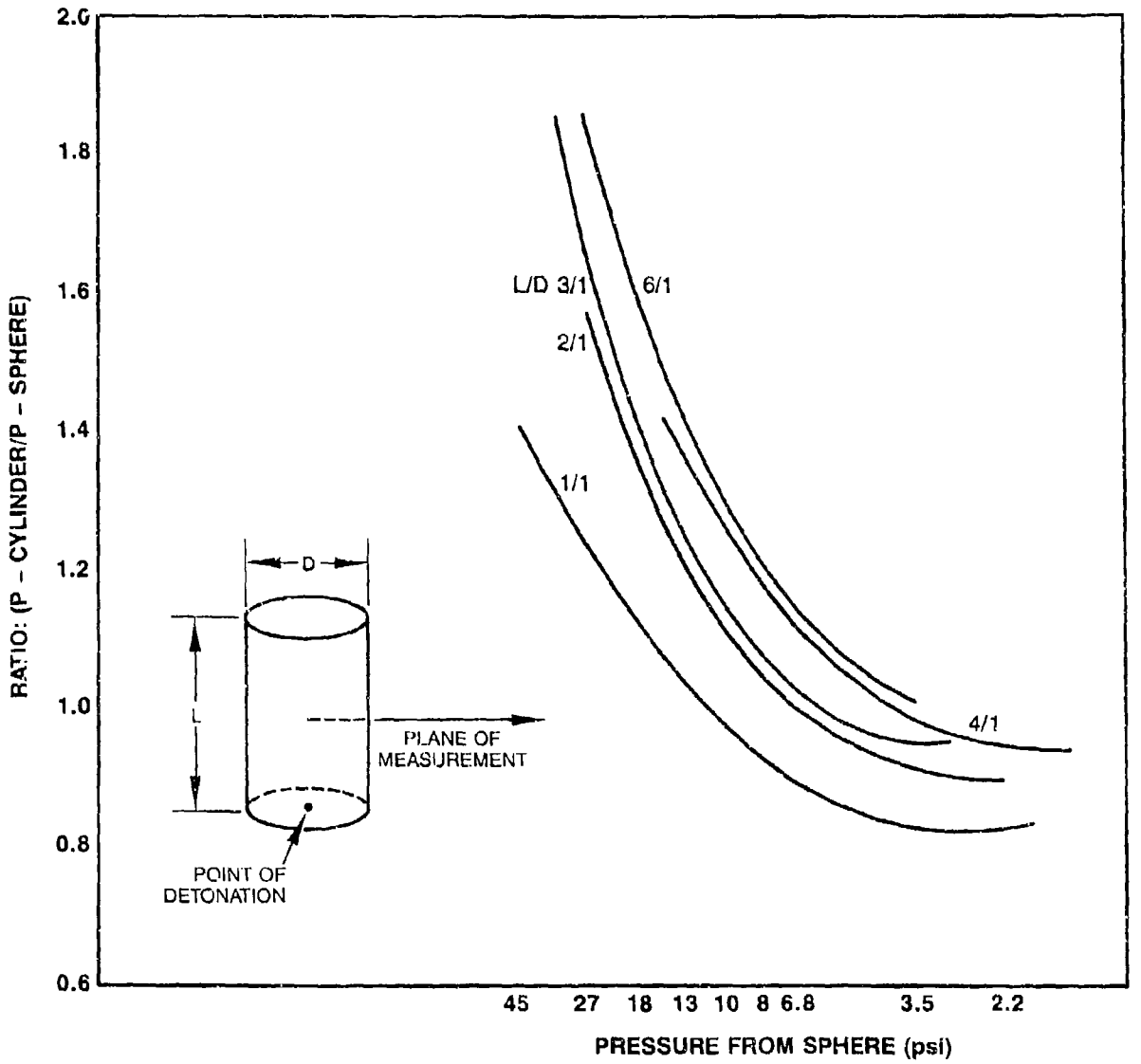
Example: For 5,000 lbs, positive duration at 110 feet is 29 msec

TNT Hemispheres
Positive Impulse vs Distance



Example: For 5,000 lbs, positive phase impulse at 110 feet is 210 psi-msec

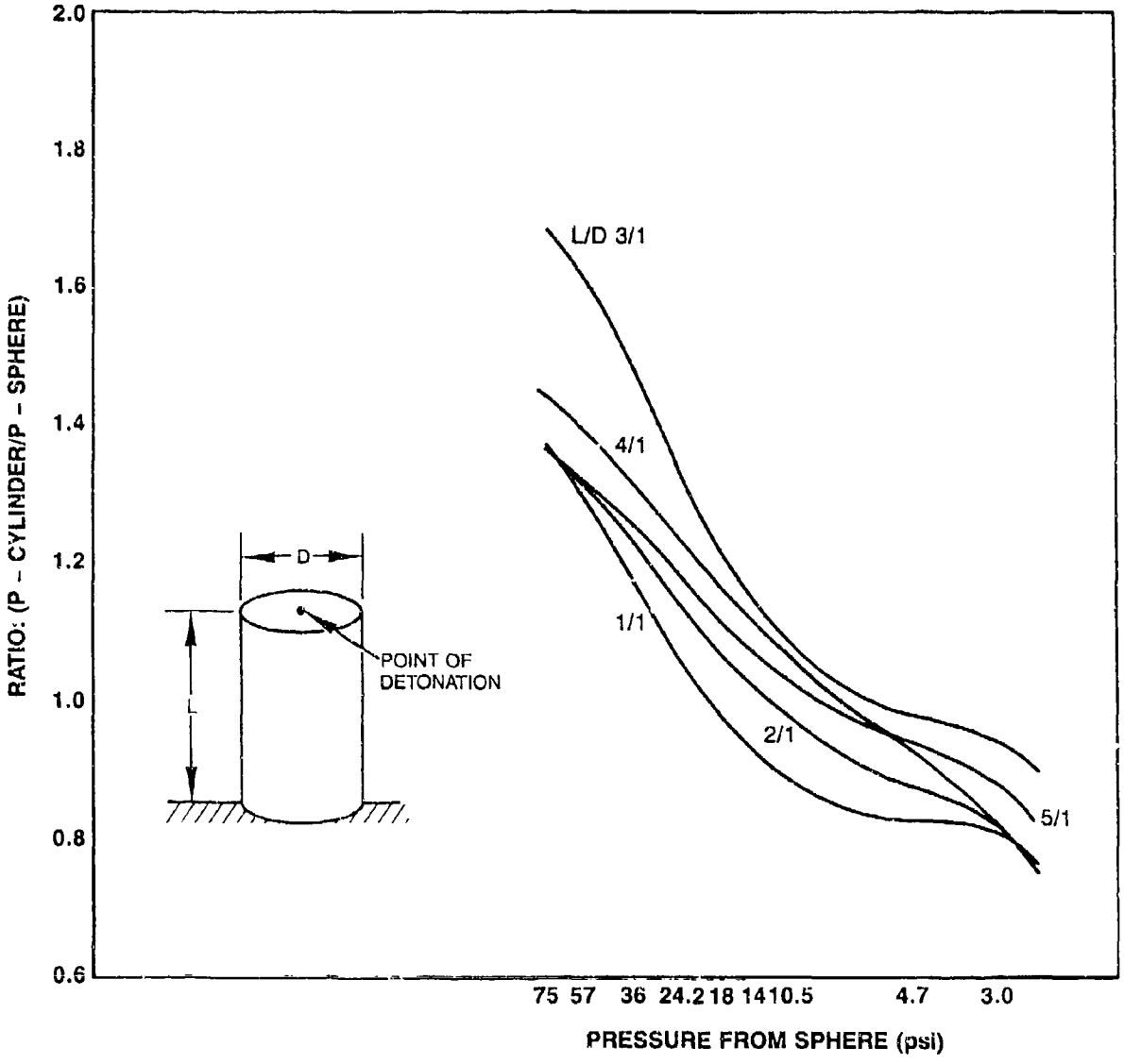
Free-Air TNT Pressure Ratio
Cylinder/Sphere



Example: What is the pressure 90 feet away from a 5,000-pound pentolite cylinder with an L/D = 2/1 detonated in free air?

1. From page 23: pentolite equivalent weight = 1.17; therefore, 5,000 pounds pentolite = 5,850 pounds TNT.
2. From page 2 overlay, at 90 feet from a 5,850-pound TNT sphere, the overpressure = 27 psi.
3. From page 12, for 27 psi from a sphere, $P_c/P_s = 1.58$ for an L/D = 2/1. Therefore, $P_c = 1.58 \times 27 = 42.7$ psi.

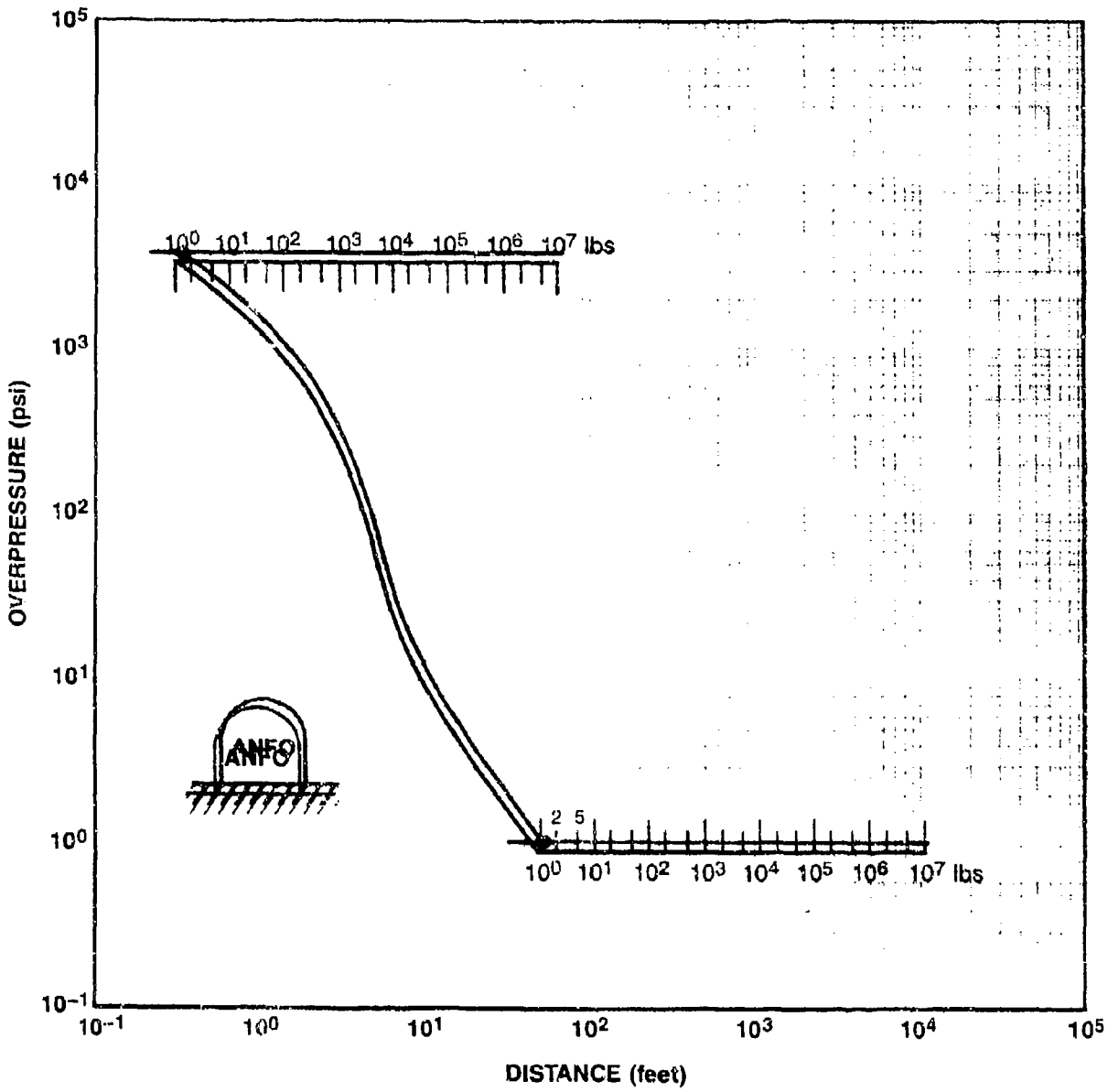
Surface TNT Pressure Ratio
Cylinder/Sphere



Example: What is the pressure 30 feet from an L/D = 3/1 TNT cylinder weighing 216 pounds?

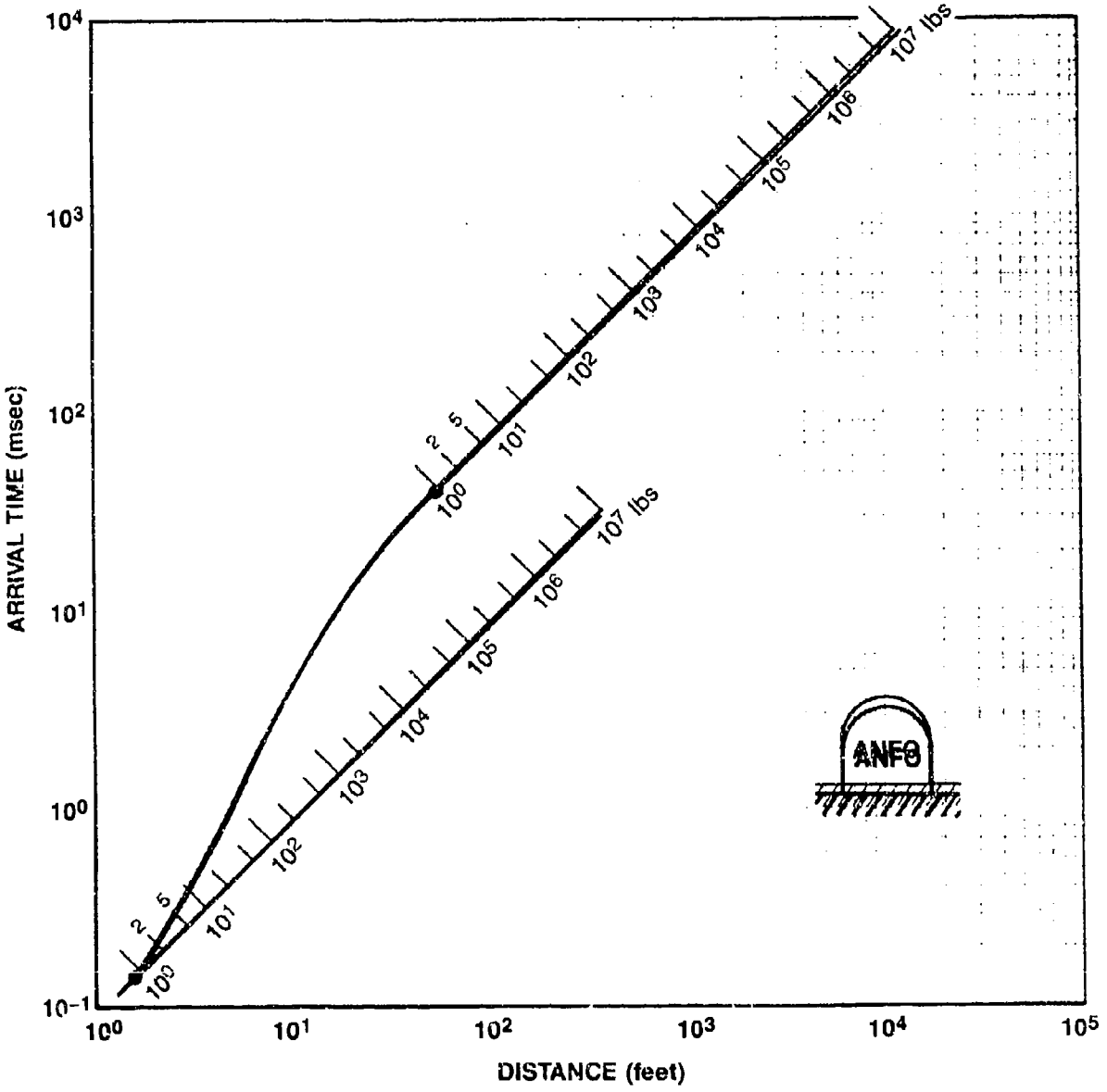
1. From page 3 overlay, at 30 feet from a 216-pound TNT sphere tangent to the surface, the overpressure = 57 psi.
2. From page 13, for 57 psi from a sphere, $P_c/P_s = 1.62$ for an L/D = 3/1. Therefore, $P_c = 1.62 \times 57 = 92.3$ psi.

ANFO Domed Cylinders (L/D = 0.75)
Overpressure vs Distance



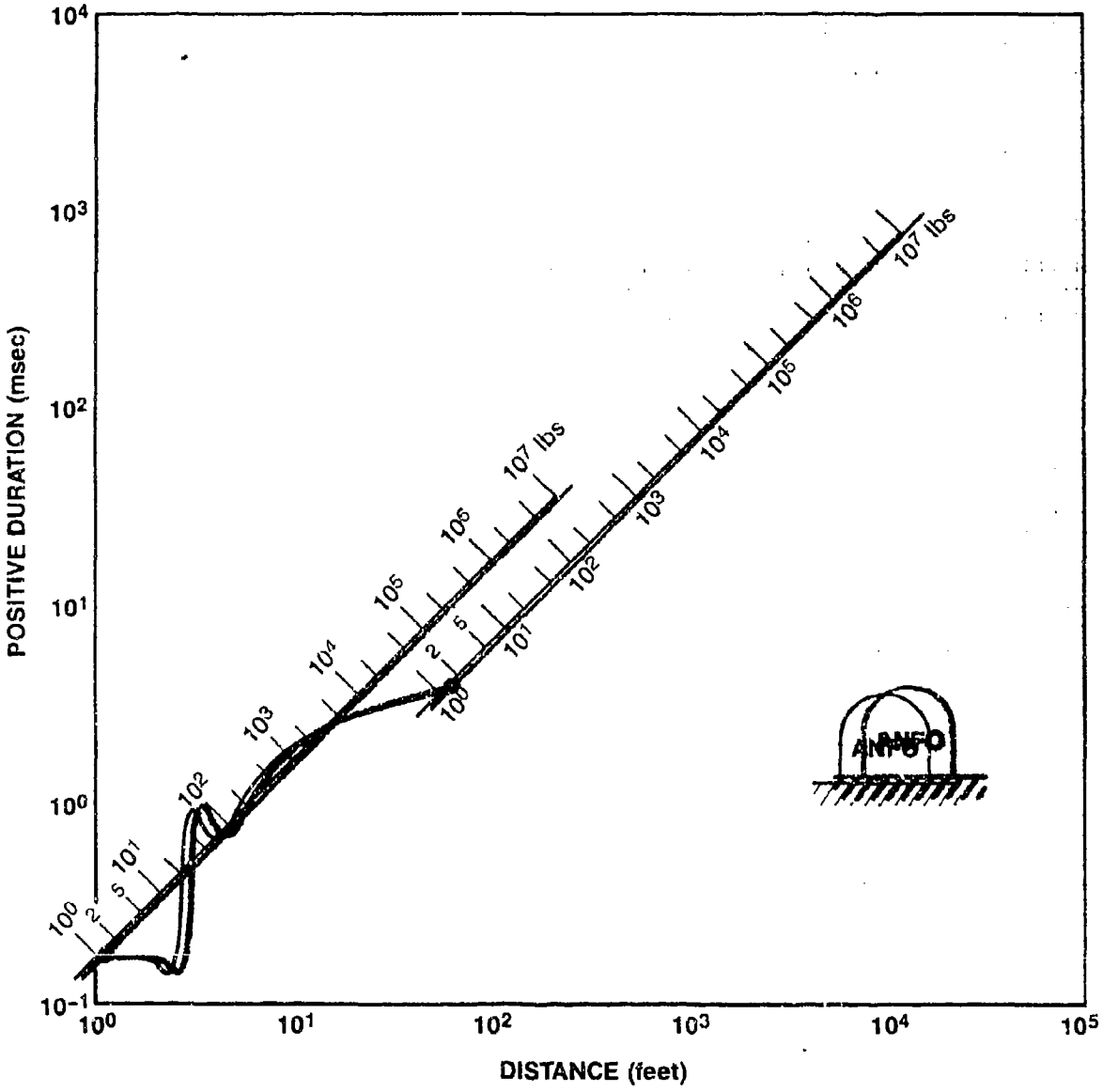
Example: For 100,000 lbs, at 200 feet, pressure = 110 psi

ANFO Domed Cylinders (L/D = 0.75)
Arrival Time vs Distance



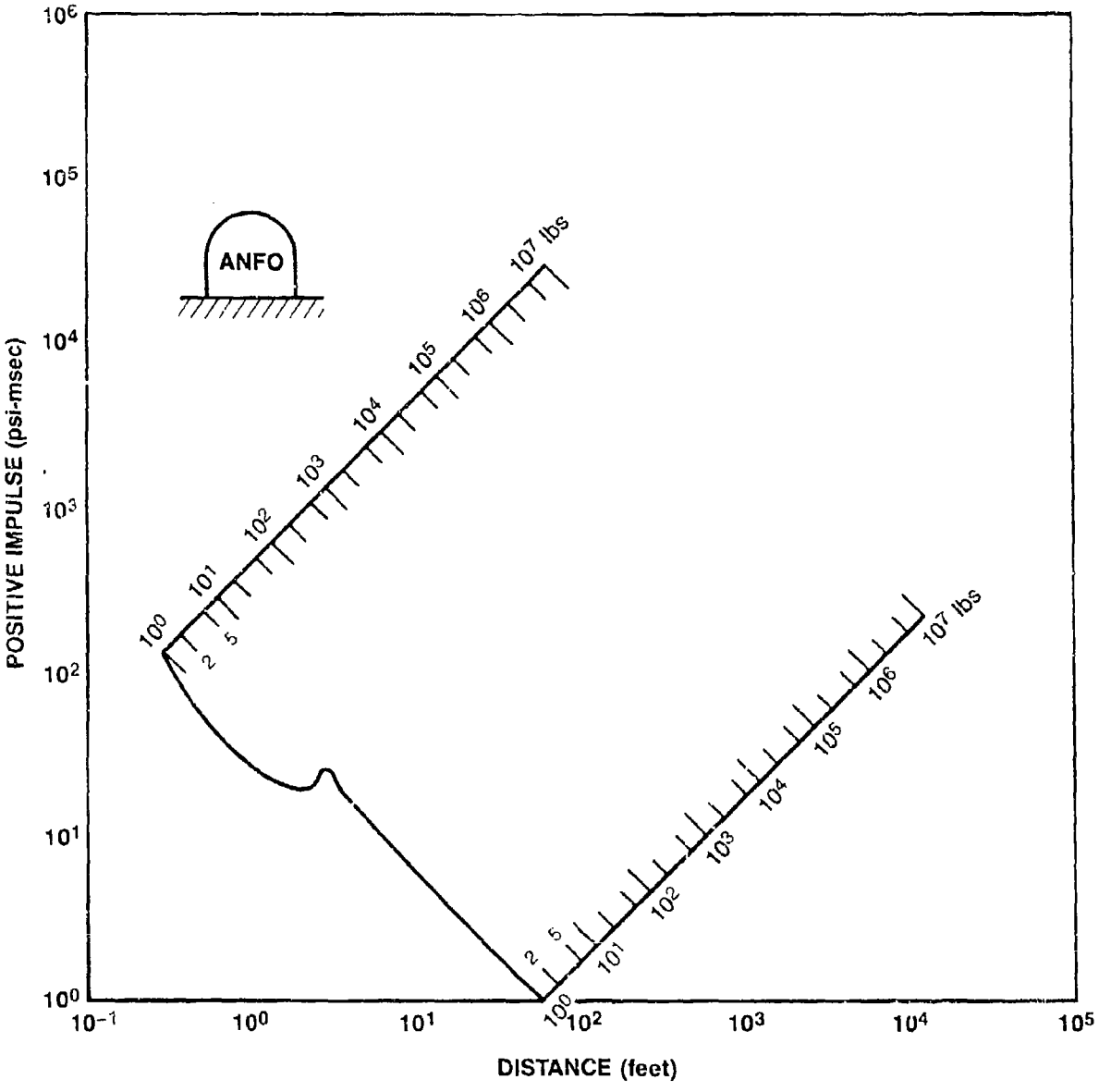
Example: For 100,000 lbs, at 200 feet, arrival time = 34 msec

ANFO Domed Cylinders (L/D = 0.75)
Positive Duration vs Distance



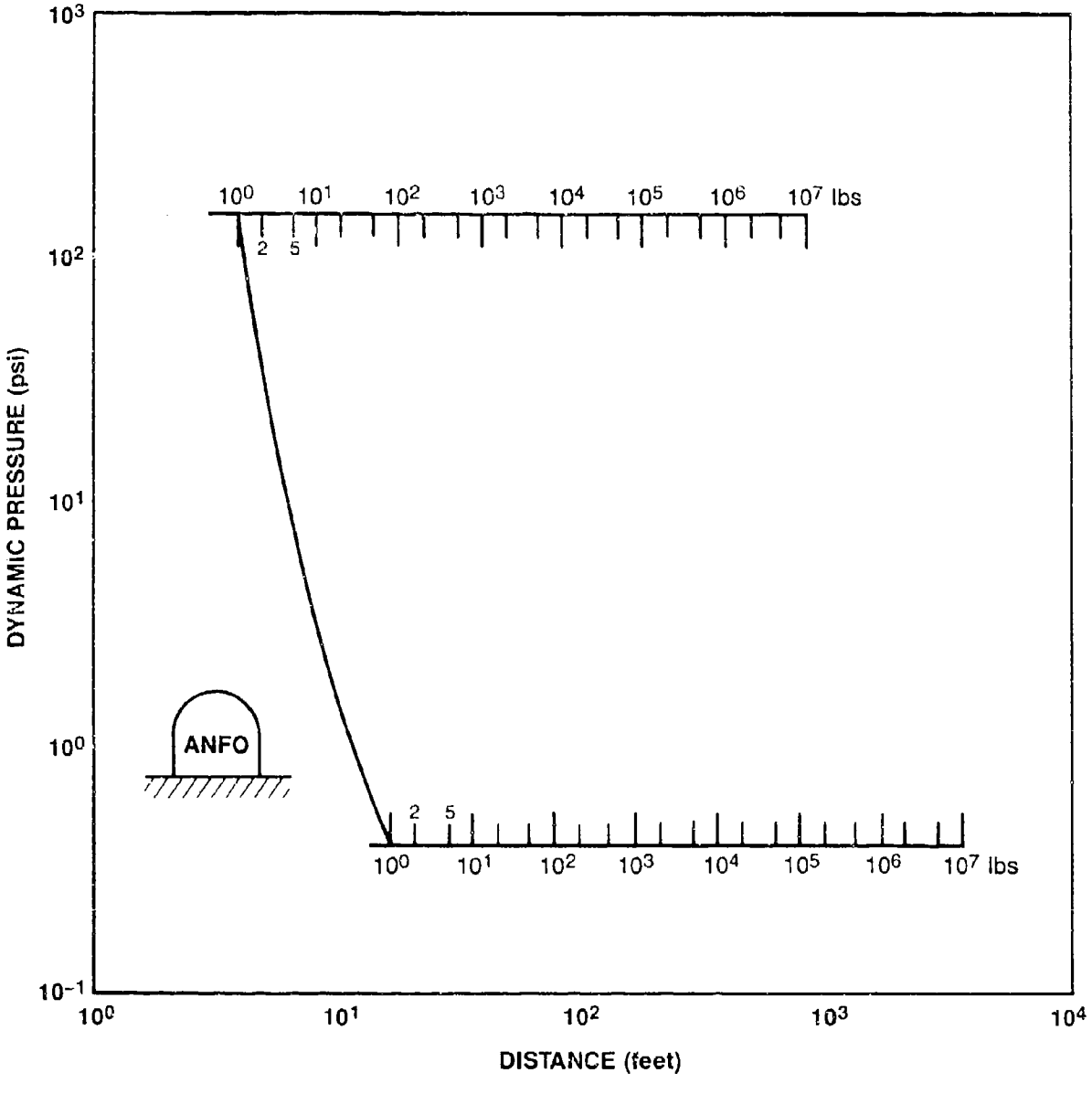
Example: For 100,000 lbs, at 200 feet, positive duration is 32 msec

ANFO Domed Cylinders (L/D = 0.75)
Positive Impulse vs Distance



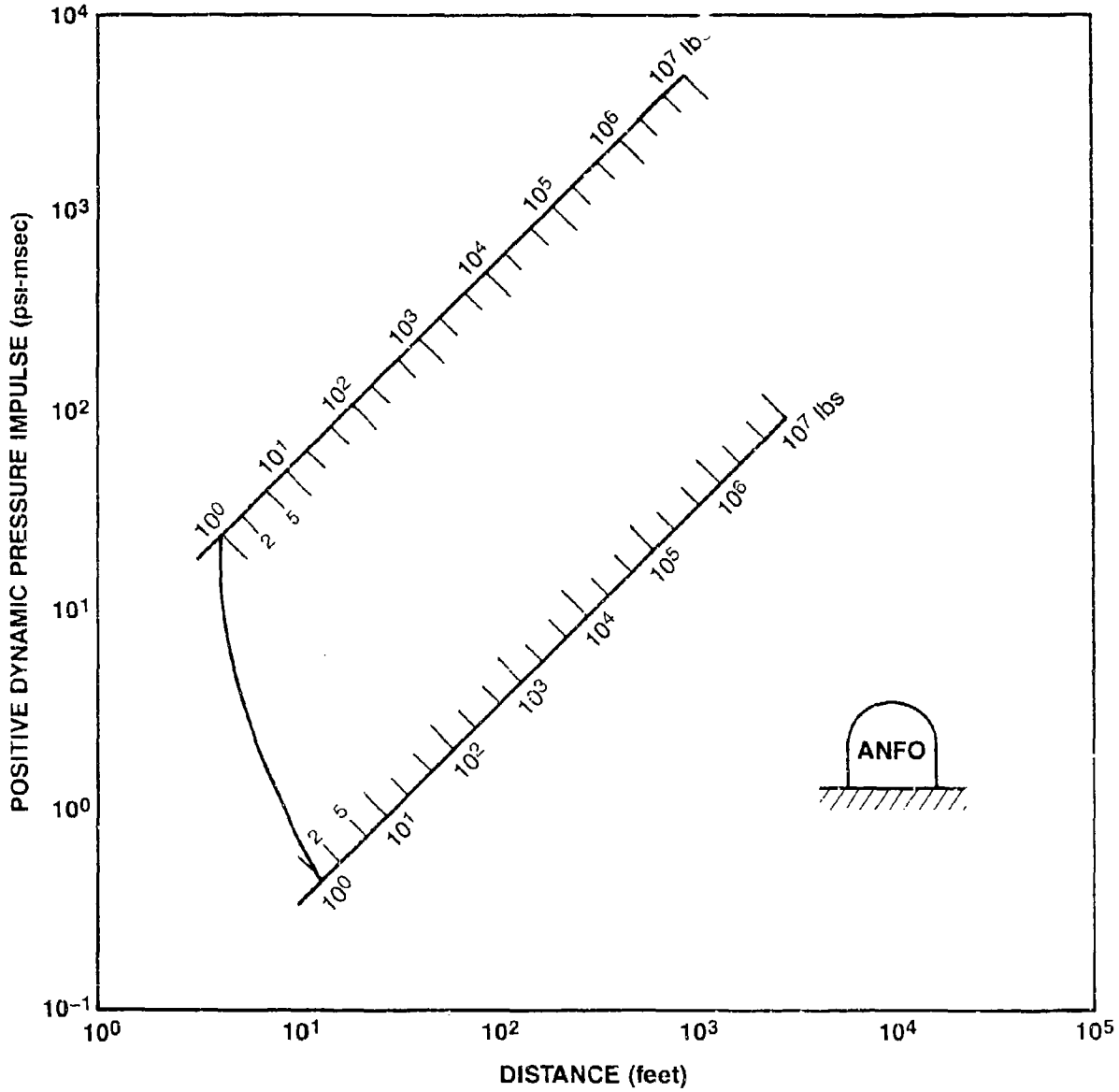
Example: For 100;000 lbs, at 200 feet, positive impulse = 750 psi-msec

ANFO Domed Cylinders (L/D = 0.75)
Positive Dynamic Pressure Impulse vs Distance



Example: For 100,000 lbs, at 200 feet, dynamic pressure = 85 psi

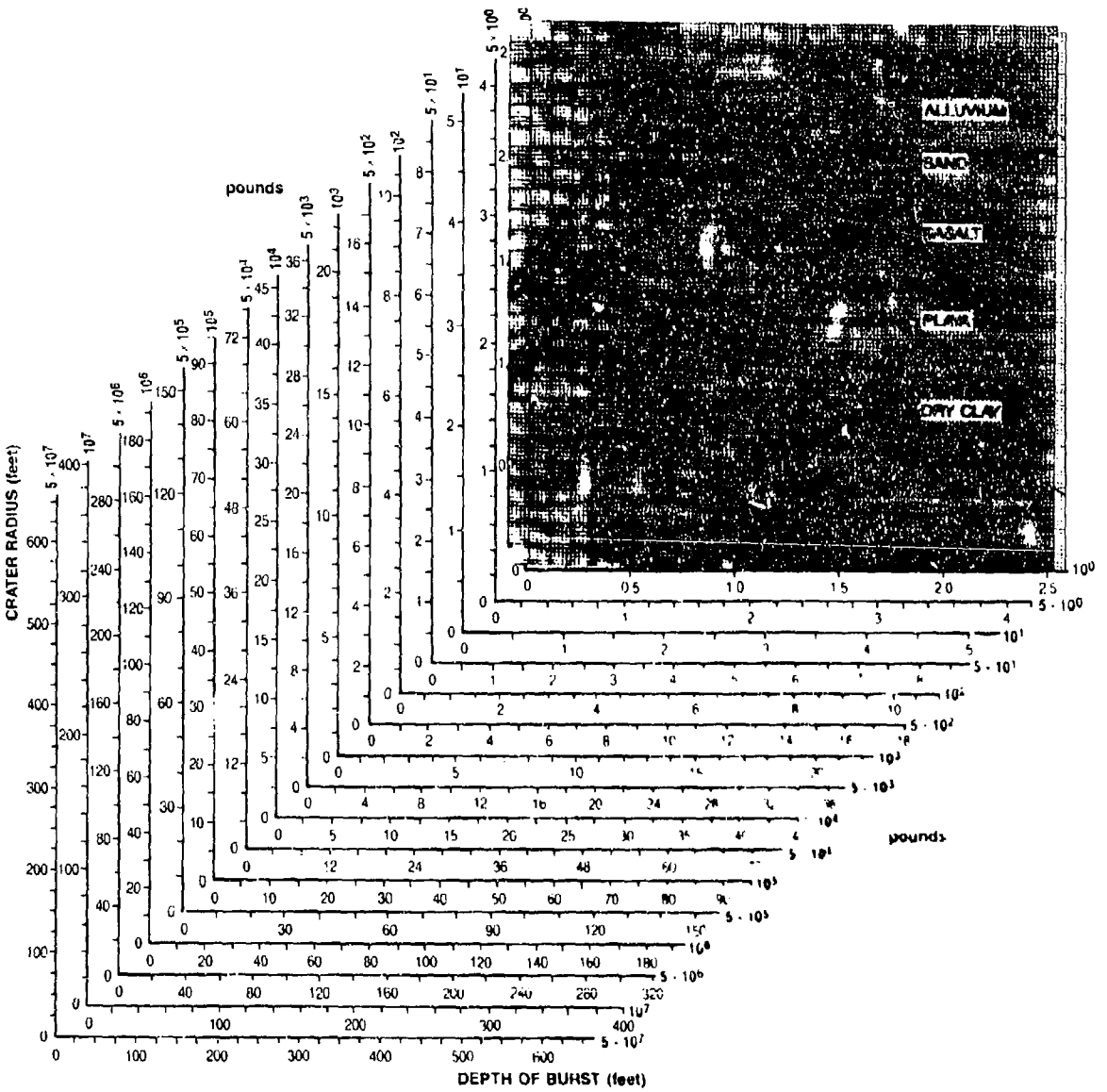
ANFO Domed Cylinders (L/D = 0.75)
Positive Dynamic Pressure Impulse vs Distance



Example: For 100,000 lbs, at 200 feet, dynamic pressure impulse = 600 psi-msec

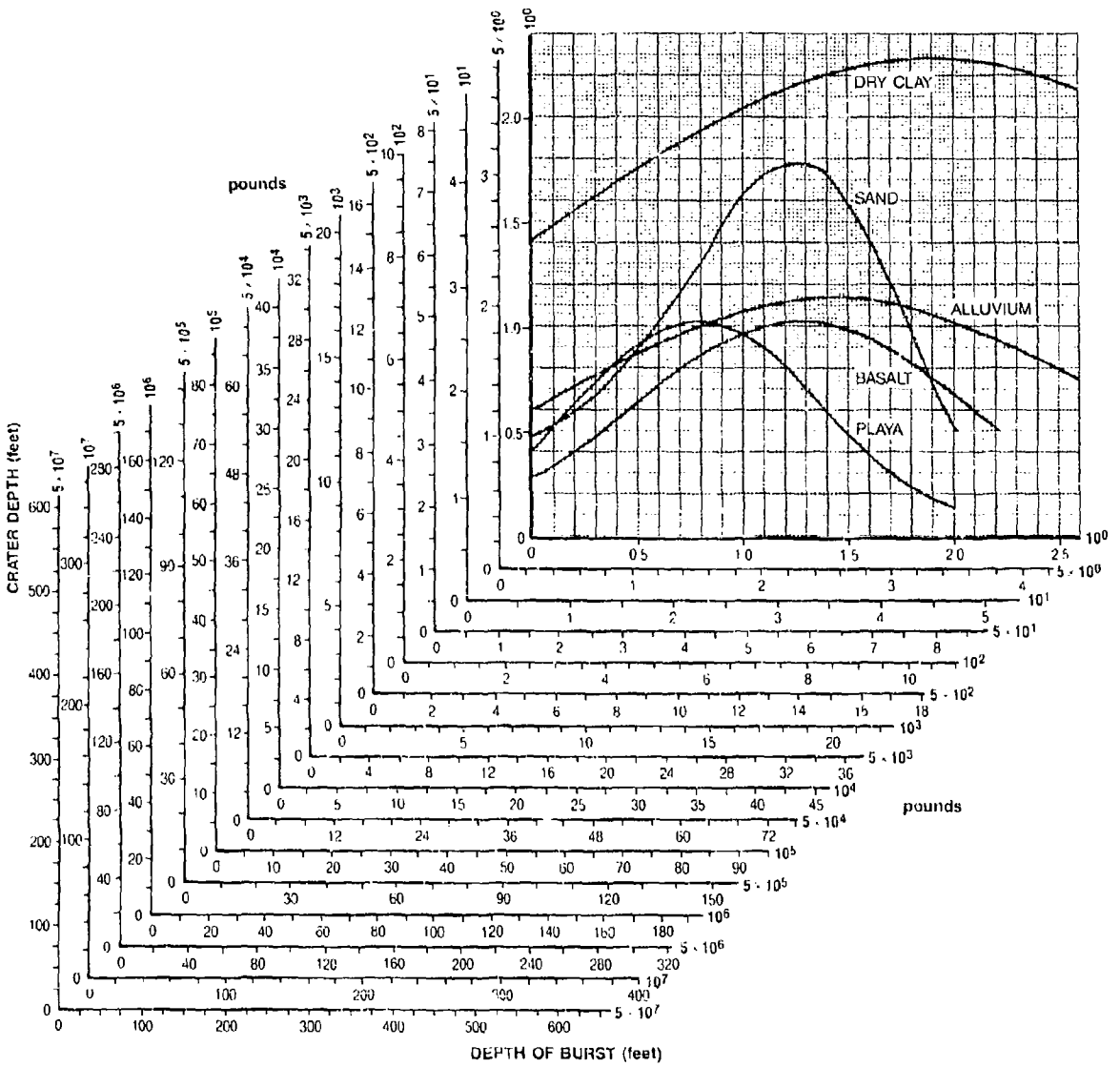
Section 2
CRATERS

TNT Spheres
Apparent Crater Radius vs Depth of Burst



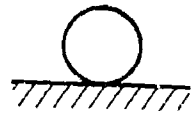
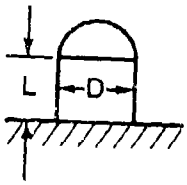
Example: For 10,000 lbs, for a depth of burst of 25 feet in dry clay, apparent crater radius = 17 feet

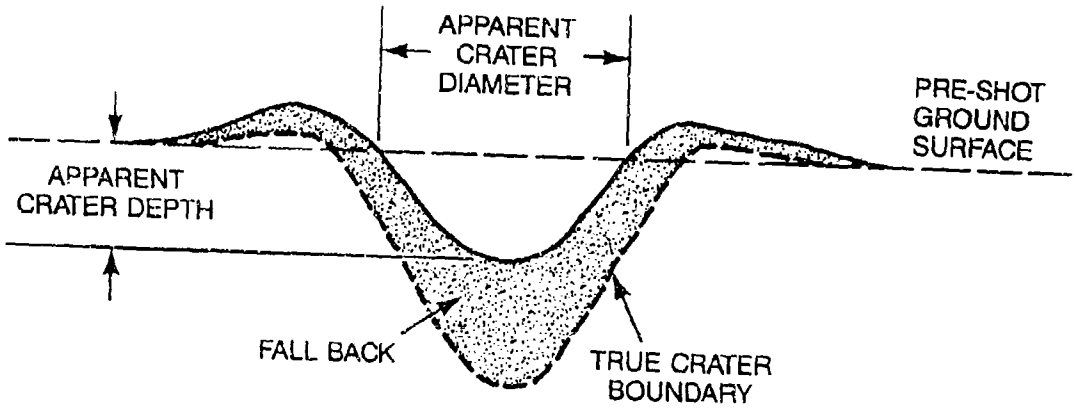
TNT Spheres
Apparent Crater Depth vs Depth of Burst



Example: For 10,000 lbs, for a depth of burst of 25 feet in dry clay, apparent crater depth = 39 feet

Multiplying Factors for Charges of Different Geometries

CHARGE GEOMETRY	RADIUS	DEPTH
 HALF BURIED SPHERE	1.0	1.0
 SURFACE TANGENT SPHERE	0.74	0.61
 HEMISPHERE	0.97	1.08
 DOMED CYLINDER (L/D = 0.75)	0.6	0.63



Apparent Crater Dimensions for Half-Buried Spheres, Surface Tangent Spheres, Hemispheres, and Domed Cylinders (L/D = 0.75)

To obtain the apparent crater radii and depths for charges of shapes other than spherical, use the spherical TNT surface burst data, i.e., depth of burst = 0, and multiply the dimensions by the values shown in the table. If the explosive is other than TNT, first determine the TNT equivalence of the test explosive (see page 23), e.g., 620 tons ANFO = 500 tons TNT.

Section 3
MISCELLANEOUS

Equivalent Weights For Peak Pressure
(Referenced to TNT)

EXPLOSIVE	EQUIVALENT WEIGHT	CHANGE IN DISTANCE FOR GIVEN PRESSURE (percent)
TNT	1.0	0
PENTOLITE	1.17	+5
TRITONAL	1.1	+3
H-6	1.31	+9
HBX	1.18	+6
ANFO (94/6)	0.82	−6
NITROMETHANE	1.0	0
DYNAMITES	0.7 to 0.9	−11 to −3

PROPELLANTS

LIQUID, e.g., LOX/H_2, $W_{TNT}\ (MAX) \approx 4\ W_P^{2/3}$

SOLID 0 to 1.25 (according to type and size)

$$EQ\ WT_{EXPL\text{''}X\text{''}} = \frac{W_{TNT}}{W_{EXPL\text{''}X\text{''}}}$$

Example: What weight of ANFO gives the same pressures as 1,000 pounds of TNT?

$$0.82_{ANFO} = \frac{1{,}000\ lbs_{TNT}}{W_{ANFO}}\ ;\quad W_{ANFO} = 1{,}219.5\ lbs$$

or 1,000 lbs TNT = 1,200 lbs ANFO

For the same weight of explosive, the distance for a given pressure is 6 percent less for ANFO than for TNT.

Scaling Procedures

As an alternative to the overlays, all the 1-pound *airblast* curves in this manual can be scaled to other, new yields via the following steps:

1. For arrival time, positive duration, and dynamic pressure impulse:
   - Determine the cube root of the new yield (weight of charge) [see page 25].
   - Divide the distance or the effects parameter of interest by this cube root to get scaled parameter.
   - On the 1-pound curve, read the value for the scaled parameter of interest (Y axis) versus the scaled distance (X axis).
   - Multiply this scaled effects value by the cube root of the new yield to obtain the answer.
2. For overpressure and dynamic pressure:
   - Determine the cube root of the new yield (weight of charge) [see page 25].
   - Divide the distance by this cube root to get scaled distance.
   - On the appropriate pressure curve, read the pressure at this scaled distance; this pressure is the answer.

Examples:

What is the arrival time at 110 feet from a 5,000-pound hemispherical TNT charge?

1. From page 25, cube root of 5,000 = 17.1
2. Scaled distance = 110/17.1 = 6.43 feet
3. From page 9, at scaled distance of 6.43 feet, scaled arrival time = 2.1 msec
4. 2.1 × 17.1 = 35.9 msec (Answer).

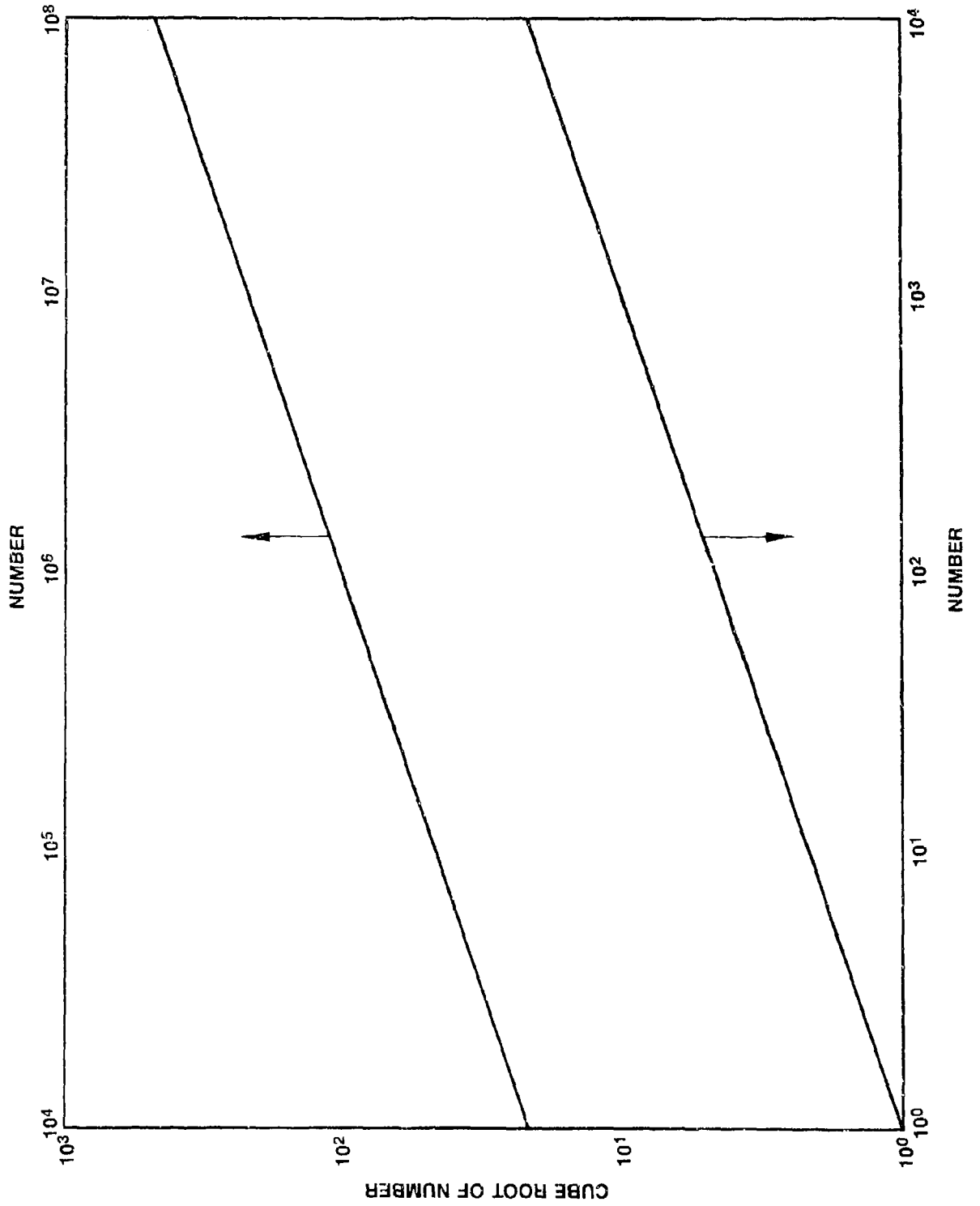
At what distance from a 5,000-pound TNT hemisphere is the arrival = 35 msec?

1. From page 25, cube root of 5,000 = 17.1
2. Scaled arrival time = 35/17.1 = 2.1 msec
3. From page 9, for scaled arrival time of 2.1 msec, scaled distance = 6.3 feet
4. 6.3 × 17.1 = 108 feet (Answer).

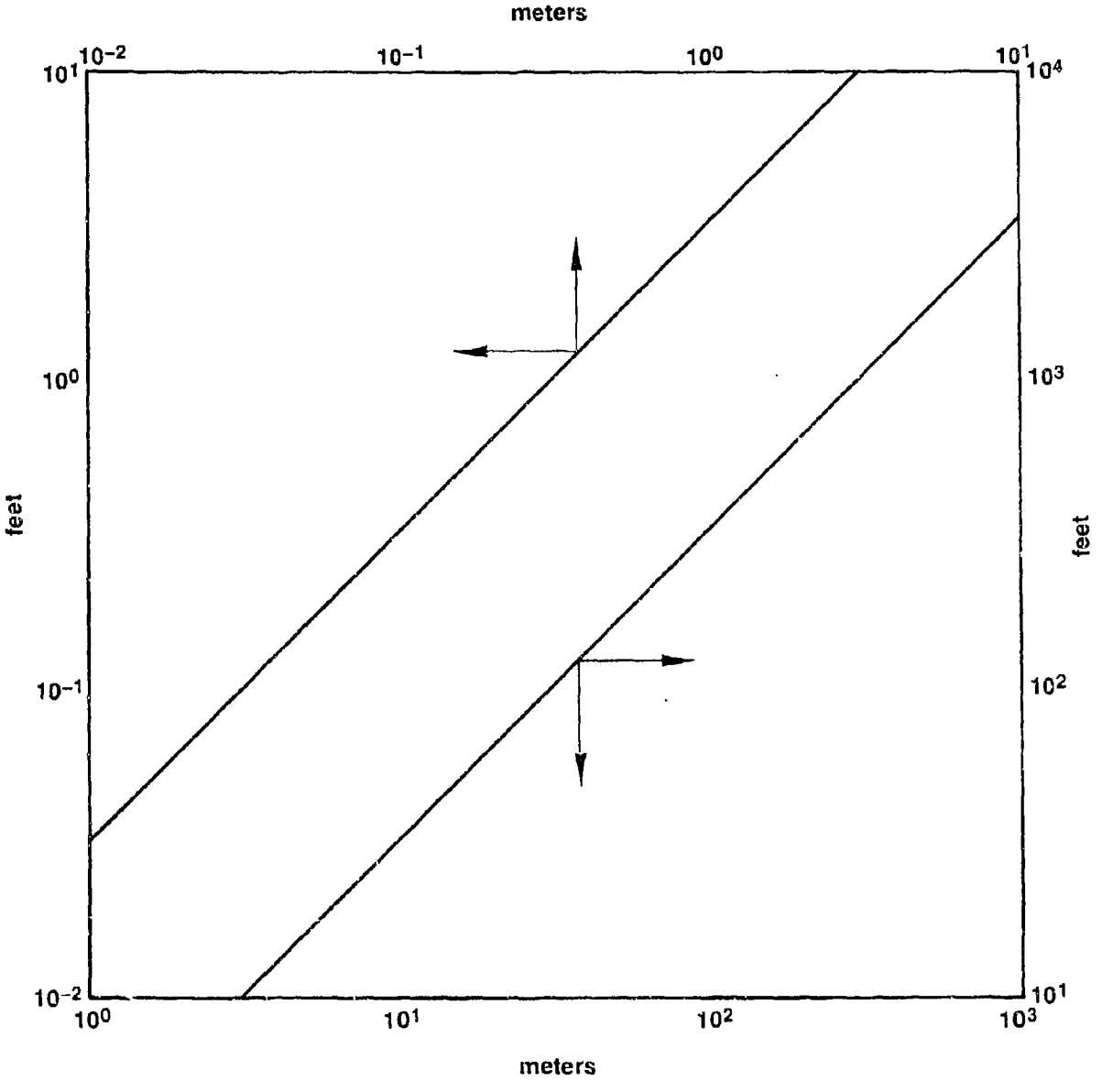
What is the pressure at 110 feet from a 5,000-pound TNT hemisphere charge?

1. From page 25, cube root of 5,000 = 17.1
2. Scaled distance = 110/17.1 = 6.43 fe
3. From page 8, at a scaled distance of 6.43 feet, the overpressure = 23 psi (Answer).

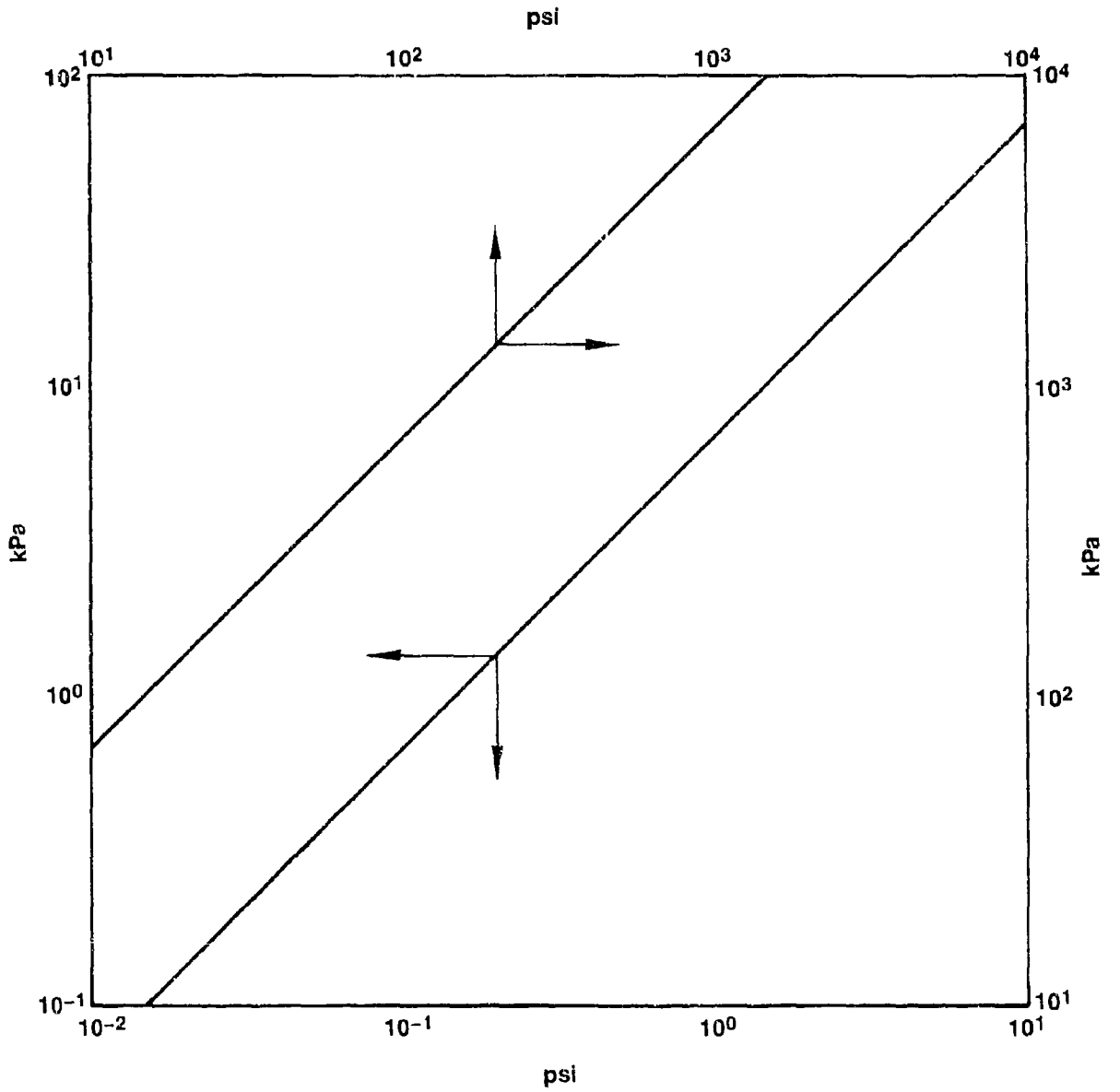
Cube Root of Numbers



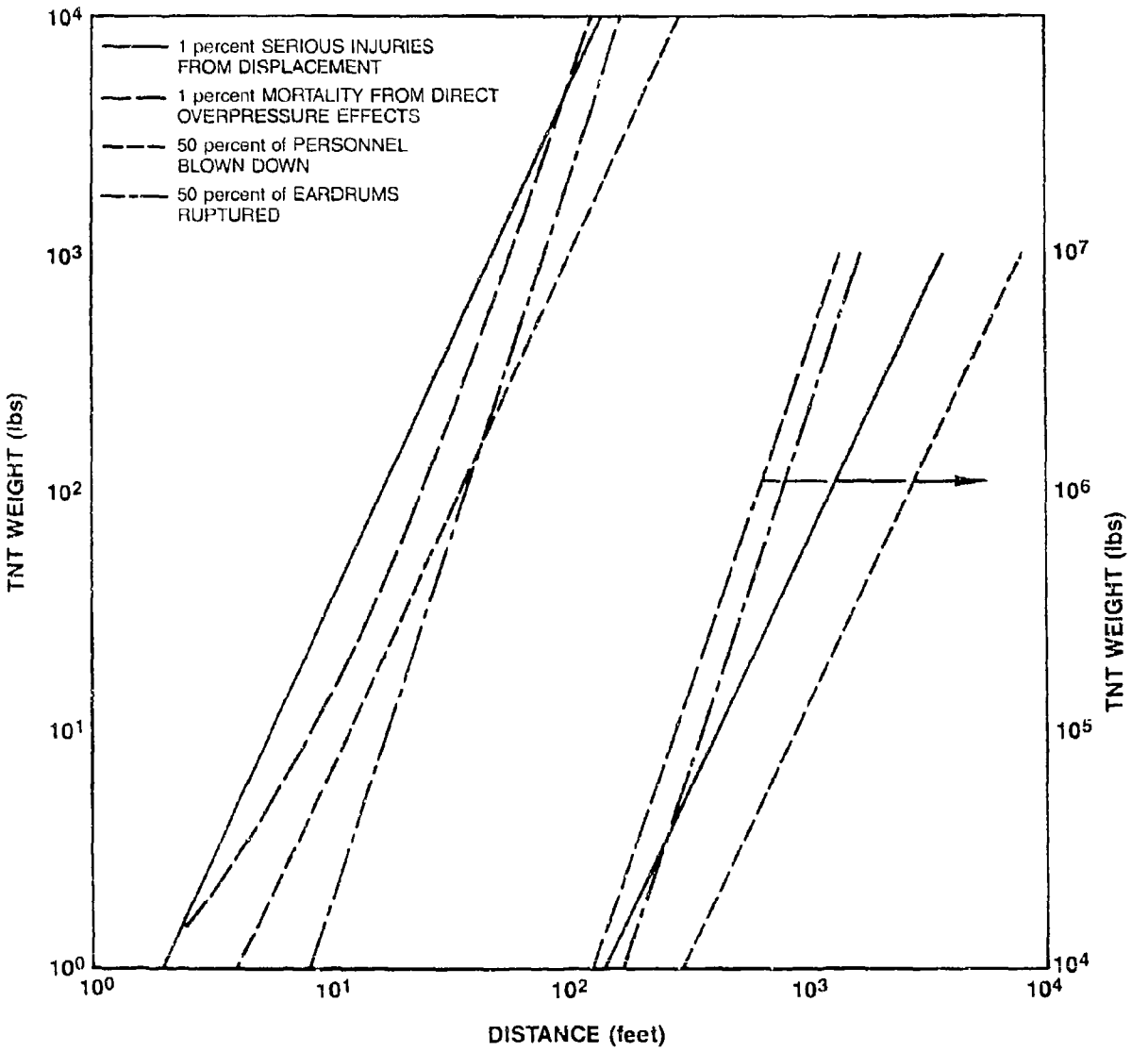
Meter/Feet Conversion



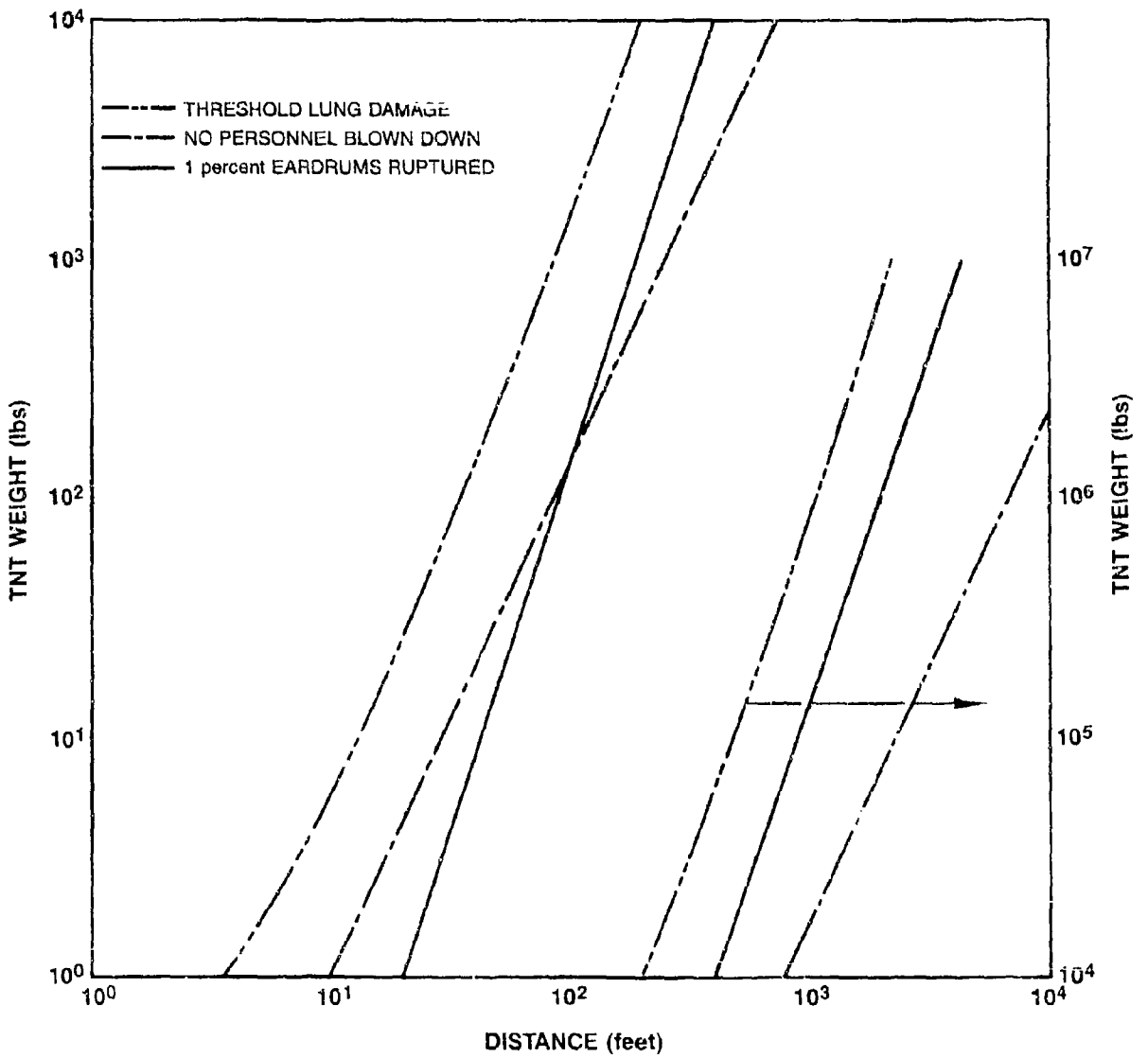
psi/kPa Conversion



Airblast Criteria for Personnel Standing in the Open
(Part 1)



Airblast Criteria for Personnel Standing in the Open (Part 2)



Section 4
SOURCES OF INFORMATION

Sources of Information

TNT Spheres (pp. 2–6), TNT Cylinders (pp. 12–13), TNT Craters (pp. 20–21)

The basic data for the indicated pages were obtained from *Explosion Effects and Properties—Part 1, Explosion Effects in Air*, M.M. Swisdak, Naval Surface Weapons Center, White Oak, Maryland, Report NSWC/WOL/TR75-116, October 1975. Other sources considered: *Structures to Resist the Effects of Accidental Explosions*, TM 5-1300/NAVFAC P-397/AFM 88-22; personal communications with R.E. Reisler, Ballistic Research Laboratories, Aberdeen, Maryland, June 1983, for height-of-burst information; *Airblast from One Pound Cylindrical Charges Positioned Vertically on the Ground*, R.E. Reisler, D.P. LeFevre, Ballistic Research Laboratories, Aberdeen, Maryland, BRL Interim Memorandum Report 42, April 1972.

Charge Shape Effect on Pressure (p. 7)

"Watch Your Equivalent Weight," J. Petes, *Proceedings of the 12th Explosives Safety Seminar*, Armed Services Explosive Safety Board, Washington, D.C., August 1970.

TNT Hemispheres (pp. 8–11)

Air Blast Parameters Versus Distances for Hemispherical TNT Surface Bursts, C.N. Kingery, BRL Report 1344, June 1966, Ballistic Research Laboratories, Aberdeen, Maryland.

ANFO Domed Cylinder (pp.14–19)

User's Guide and History of ANFO as a Nuclear Weapons Effect Simulation Explosive, J. Petes, R. Miller, R. McMullan, Kaman–Tempo, Alexandria, Virginia, KT–83-012(R), DNA-TR-82-156. This report considers the 10-year development and 7-year experimental use of unconfined (uncased) ANFO for nuclear weapon effects simulation bringing together the explosion effects of ANFO charges in one volume. *Note*: although the ANFO sheets show 1-pound curves, this is done strictly to aid scaling to larger yields. Because of the large critical diameter of unconfined ANFO charges, the curves should be used only for charges weighing 500 pounds and more. *Note also* that the curves are for a specific geometry of the charge with the ratio of the length of the cylindrical portion of the charge to the diameter equaling 0.75; the dome is hemispherical.

Charge Shape Effect on Craters (p. 22)

The information on this page was developed from an examination of crater data obtained on large tests using TNT and ANFO explosives. For the tests considered, crater diameters were within 18 percent of those measured and crater depth within 8 percent. The big problem in estimating crater dimensions in any scheme is in determining the applicable soil description.

Equivalent Weights (p. 23)

The values given for the military explosives TNT, Pentolite, Tritonal, H-6, and HBX are averages from many "standard" sources. The ANFO and dynamites equivalent weights are from NSWC/WOL/TR 75-116; for nitromethane, the value comes from *Pre-Mine Throw IV—Free Field Experiment*, G. Teel, Ballistic Research Laboratories, Aberdeen, Maryland, POR-6830, August 1975; for liquid propellants, "A Simplified Method for Estimating the Appropriate TNT Equivalent Weight from Liquid Propellant Explosions," *Proceedings of the 15th Annual Explosives Safety Seminar, September 1973*, L.D. Sutherland; and for solid propellants, *Maximum TNT Equivalence of Naval Propellants*, M.M. Swisdak, Naval Surface Weapons Center, White Oak, Maryland, NSWCTR 83-120, February 1983. *Note*: equivalent weight values are averages over a limited range of pressures, perhaps a few hundred to a few psi.

Scaling Procedure (p. 24)

The curves for the effects of 1 pound of explosive are the usually presented "scaled" curves with the X- and Y-axes showing the scaled parameters (except for pressure, which cannot be scaled). Page 7 is an example of the traditional presentation of scaled curves.

Personnel Criteria (pp. 28–29)

"Blast Criteria for Personnel in Relation to Quantity–Distance," *Proceedings of the 13th Annual Explosives Safety Seminar*, D.R. Richmond and E.R. Fletcher, Armed Services Explosive Safety Board, Washington, D.C., September 1971.

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